

JavaTM magazine

By and for the Java community 

JANUARY/FEBRUARY 2016

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The Rise and Fall of Languages in 2015

An unusually good year for Java and JVM languages

For the last few years, in my first editorial of the new year, I've looked at how programming languages fared during the previous calendar year. Despite the general perception that changes in language popularity are slow-moving affairs, programming languages often suffer sudden declines (Objective-C) or enjoy unexpected surges (Java, as I'll explain in a moment). The most widely used measure of popularity is the TIOBE Index, which counts searches for languages and normalizes the results to a percentage of the total number of searches. Whether web searches are an accurate proxy for popularity is a point of some contention; however, the TIOBE Index has one significant advantage: it provides data for the index going back 15 years. This makes it possible to identify multiyear trends easily.

Good analysis of language popularity necessarily relies on additional sources. I also rely on

data extracted from GitHub, the popular host for open source and private projects; Open Hub, which surveys all active open source projects; and Google Trends. Each measure quantifies different things, and it's important to look at the data *in context* before determining what useful information it provides.

By most measures, Java had a banner year. TIOBE just named Java Language of the Year for 2015 because it enjoyed the greatest jump of any language in terms of percentage of searches. TIOBE attributes this surge to the use of Java on Android. I believe this is true, but it's only part of the story. The rapid adoption of Java 8 certainly contributed, too. Java's surge definitively lays to rest the trend of click-bait articles inquiring "Is Java Dead?" in which pundits invariably concluded after lots of explanation that it's not dead.

GitHub is a good way to measure popularity

PHOTOGRAPH BY BOB ADLER/GETTY IMAGES

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among younger programmers. Here, too, Java is hot. It currently sits behind only JavaScript in popularity. This represents a remarkable ascent. GitHub initially rose to popularity in the Ruby community. In 2008, Java was the seventh most popular language on GitHub; Ruby was first. Java's ascent of five positions in the intervening years is unmatched. During the same period, no programming language has managed to rise more than two slots. I expect its popularity to continue due to Java's ubiquity on the cloud (every major cloud provider supports it) and its central role in the Internet of Things.

Among third-party JVM languages, the only two entrants to make it into the TIOBE top 50 or to be ranked by Open Hub are Groovy (#17) and Scala (#30). On TIOBE, Groovy had a banner year. It's hard to know the cause of this, although progress in the chief complaint against it—performance—has surely helped. In open source projects, Scala has the upper hand in popularity. This suggests that Groovy is more popular in business contexts, which is a transition that Scala must make in the next few

years in order to move out of the margins. I'm curious to see if it will cross this chasm. Several years ago, the biggest complaints about Scala were the binary incompatibility of new releases, slow compile times, and language complexity. Today, the last two concerns remain important obstacles. Meanwhile, languages such as Kotlin, which is viewed by many as a direct competitor, are putting pressure on Scala. So is Java indirectly. Scala's claim to fame is that it enables developers to mix object-oriented (OO) and functional paradigms. But Java 8 introduced functional programming elements, which, while far more modest than Scala's, might induce businesses thinking of looking to Scala for its functional-OO hybrid qualities to stay put.

Developers who prefer the functional paradigm will be pleased to know that TIOBE expects that Clojure, with its Lisp-like syntax and currently sitting in third place among JVM languages, will soon advance to the honor roll of top 50 languages. Meanwhile, other functional languages, such as Haskell and Erlang, both broke into the top 40 spots.

In non-JVM languages, perhaps

the most interesting trend, which appears in multiple indexes, is that JavaScript's popularity appears to have peaked. A few years ago, its ubiquity on front ends (both web and mobile) and the advent of Node.js suggested that it might become the new universal programming language (see Atwood's Law). But limitations of the language make it difficult to use on large-scale projects. The result has been the growth of JavaScript transpiling alternatives such as Dart, CoffeeScript, and TypeScript. Of these, I personally most admire TypeScript, which also appears to be gaining the most traction among developers. I'll be curious to see whether the approval of the ECMAScript 6 standard (also known as ECMAScript 2015) in June of last year will improve JavaScript's popularity. We'll check in next year.

Language features and projections of future language adoption are among the most enjoyable discussions in programming. Let me know if you have different views from mine.

Andrew Binstock, Editor in Chief
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SEPTEMBER/OCTOBER 2015

More JavaFX and Introductory Articles

Java Magazine used to run articles for developers new to Java in every issue. In addition, there were occasional articles on JavaFX. Is it possible to continue publishing such articles?

—Marius Claassen

Editor Andrew Binstock responds: Thanks for your note. Readers’ suggestions about what to cover more frequently are very helpful to us. We will be resuming the beginner series in the next issue, and it should become a regular feature. Michael Kölling—the author of the previous series on introductory topics—will be the author. His focus will be on language features, especially the dark corners where unexpected or unusual behaviors are found.

You might have seen in the September/October issue that we covered TestFX, a way of testing JavaFX apps. And we do have a couple of additional JavaFX articles in the pipeline. If we see an increase in demand for JavaFX articles, we will cover the topic even more.

How Effective Is Static Analysis?

Thank you for your editorial on the value of static analysis (“The

Unreasonable Effectiveness of Static Analysis,” September/October 2015 issue, page 3). You were kind enough to quote some of the statistics I published earlier. Let me make some comments and add some more information.

Static analysis is among the most effective forms of defect removal, and also fairly inexpensive and fairly rapid. It can be used for both development and also for removing latent bugs in legacy applications. As you pointed out, false positives are much lower today than they were 10 years ago. I think static analysis should become a standard software quality method that is used on just about 100 percent of all software applications, with one caveat—the tool is simply not available for many languages except the 30 or so most popular ones.

However, its effectiveness is undeniable. Table 1 shows the approximate defect removal efficiency (DRE) values for a sample of pretest removal and for test stages. The DRE metric was developed by IBM circa 1973 as a tool for validating the effectiveness of inspections. It is a simple metric. If developers find 90 bugs and a customer reports 10 bugs in the first three months of use, then

the DRE would be 90 percent.

The current US average for DRE is about 92 percent, but top projects can get up to 99.5 percent. This average value is based on both pretest removal and the six normal test stages used

TECHNIQUE	DEFECT REMOVAL RATE
FORMAL INSPECTIONS	87%
STATIC ANALYSIS	55%
EXTERNAL BETA TEST > 1,000 CLIENTS	52%
SYSTEM TEST—CERTIFIED TESTERS	46%
INFORMAL PEER REVIEWS	45%
SYSTEM TEST—UNCERTIFIED DEVELOPERS	36%
FUNCTION TEST	35%
COMPONENT TEST	32%
UNIT TEST	30%
EXTERNAL BETA TEST < 1,000 CLIENTS	28%
DESK CHECK	27%
PAIR PROGRAMMING	22%
ACCEPTANCE TEST	17%
REGRESSION TEST	14%
PERFORMANCE TEST	12%

Table 1. Defect removal efficiency (in descending order) for pretest and test techniques

06

We welcome comments, suggestions, grumbles, kudos, article proposals, and chocolate chip cookies. All but the last two might be edited for publication. If your note is private, please indicate this in your message. Please write to us at javamag_us@oracle.com. For other ways to reach us, see the last page of this issue.



//events/



JavaLand MARCH 8–10

BRÜHL, GERMANY

This annual conference is a gathering of Java enthusiasts, developers, architects, strategists, and project administrators. Session topics for 2016 include containers and microservices, core Java and JVM languages, enterprise Java and the cloud, front end and mobile, IDEs and tools, and the Internet of Things (IoT). After lectures on the first day of the conference, attendees get exclusive use of Phantasialand and its rides and attractions.

PHOTOGRAPH BY RACHEL TITIRIGIA/Flickr

Voxxed Days Berlin

JANUARY 27–29

BERLIN, GERMANY

Sharing the DevOxx philosophy that content comes first, Voxxed Days events see both internationally renowned and local speakers converge. Berlin topics include Java component design with Spring 4.3; microservices with Java, Spring Boot, and Spring Cloud; and simple REST APIs with Dropwizard and Swagger.

Topconf Linz

FEBRUARY 1–3

LINZ, AUSTRIA

This conference focuses on new ways to manage mobile, Java, cloud, front end, security, and more. Workshops include sketching web and app interfaces, microservices and event sourcing with Spring Boot, and software management in a lean and agile world.

Jfokus

FEBRUARY 8–10

STOCKHOLM, SWEDEN

Jfokus has run for eight years and is the largest annual Java developer conference in Sweden. Conference topics include Java SE and Java EE, the inner mechanics of the JVM, front end and web, mobile, continuous delivery and DevOps, the IoT, cloud and big data, future and trends, alternative JVM languages, and agile development.

DevNexus 2016

FEBRUARY 15–17

ATLANTA, GEORGIA

DevNexus is a conference drawing 1,700 developers, with 6 workshops, 12 tracks, and 120

presentations. Featured tracks include HTML5 and JavaScript, Java SE/Java EE/Spring, and data and integration.

Apache Hadoop Innovation Summit

FEBRUARY 18–19

SAN DIEGO, CALIFORNIA

With presentations from more than 25 hands-on industry speakers, topics covered will include MapReduce and Spark, building privacy-protected data systems, scalable data curation, best practices, and architectural considerations for Hadoop applications.

Mobile World Congress

FEBRUARY 22–25

BARCELONA, SPAIN

This industry-leading event focuses on in-depth analysis of present and future trends in the mobile industry. The 2016 MWC conference program features tracks on the IoT, smart cities, digital finance, and more.

Embedded World 2016

FEBRUARY 23–25

NUREMBERG, GERMANY

The 14th annual gathering of embedded system developers





will explore the latest developments, define trends, and once again present the key areas of focus for future developments. This is where hardware, software, and system development engineers come together to turn the next milestones of the IoT into reality.

ConFoo

FEBRUARY 24–26

MONTREAL, QUEBEC, CANADA

ConFoo is a multitechnology conference for web developers, featuring about 150 presentations by popular international speakers. Past sessions have included

Testing Java EE Applications Using Arquillian, by Reza Rahman, and Hybrid Mobile Development with Apache Cordova and Java EE 7, by Ryan Cuprak.

Riga Dev Day

MARCH 2–4

RIGA, LATVIA

This event is a joint project by Google Developer Group Riga, Java User Group Latvia, and Oracle User Group Latvia. By and for software developers, Riga Dev Day focuses on 25 of the most-relevant topics and technologies for that audience. Tracks include JVM and web development, databases, DevOps, and case studies.

QCon London

MARCH 7–9

LONDON, ENGLAND

QCon is designed for technical team leads, architects, engineering directors, and project managers who influence innovation in their teams. Topics include what to expect in Java 9 and Spring 5, containers in production, microservices for mega-architectures, full-stack JavaScript, and data science and machine learning methods.

EclipseCon 2016

MARCH 7–10

RESTON, VIRGINIA

EclipseCon is all about community. Contributors, adopters, extenders, service providers, consumers, and business and research organizations gather to share their expertise and learn from each other. Topics this year include an introduction to the Eclipse Che next-generation Java IDE, hawkBit and software updates for the IoT, a faster index for Java, and Java 9 support in Eclipse.

jDays

MARCH 8–9

GOTHENBURG, SWEDEN

jDays is a Java developer conference covering Java/Java EE, architecture, security, DevOps, cloud and microservices, testing, JavaScript, IoT trends, methodologies, and tools.

CITCON

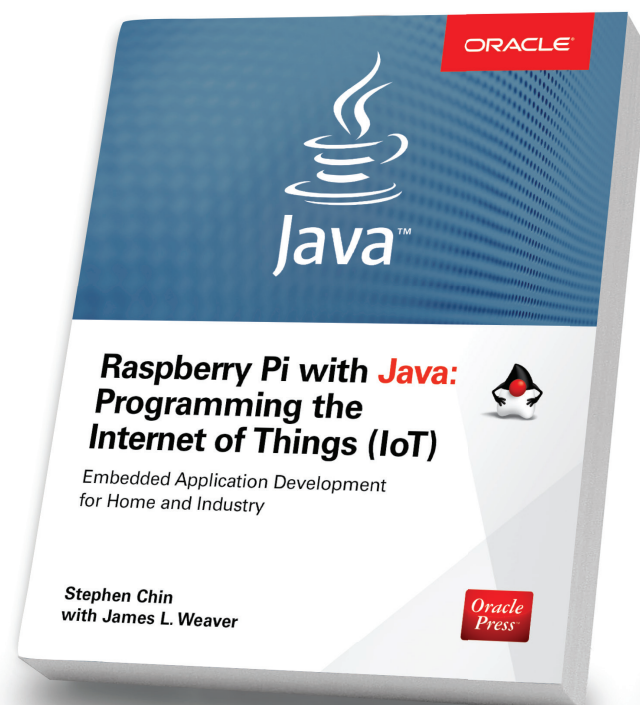
LATE MARCH (DATE TO BE ANNOUNCED)

PERTH, AUSTRALIA

CITCON, the Continuous Integration and Testing Conference, is a worldwide series of free “Open Spaces” events for developer-testers, tester-developers, and anyone else with an interest in continuous integration and the type of testing that goes along with it.

Have an upcoming conference you’d like to add to our listing? Send us a link and a description of your event at least four months in advance at javamag_us@oracle.com. We’ll include as many as space permits.

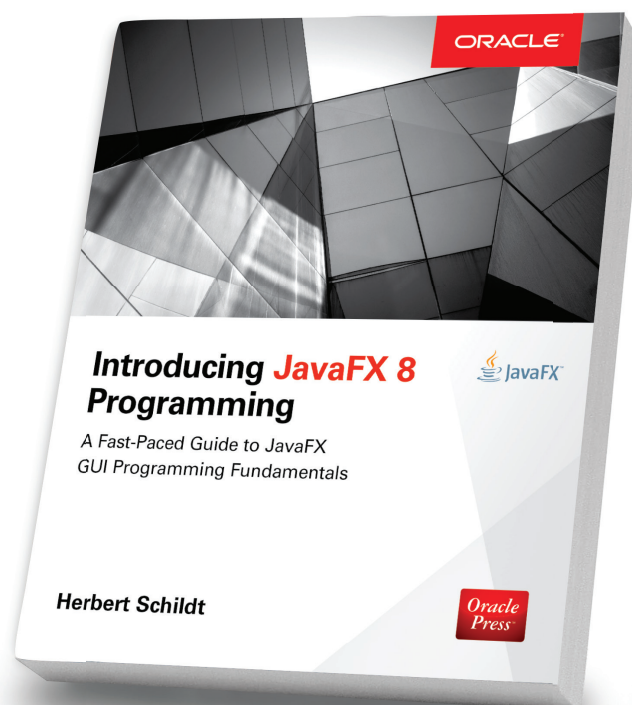
Written by leading Java experts, Oracle Press books offer the most definitive, complete, and up-to-date coverage of Java available.



**Raspberry Pi with Java:
Programming the
Internet of Things (IoT)**

Stephen Chin, James Weaver

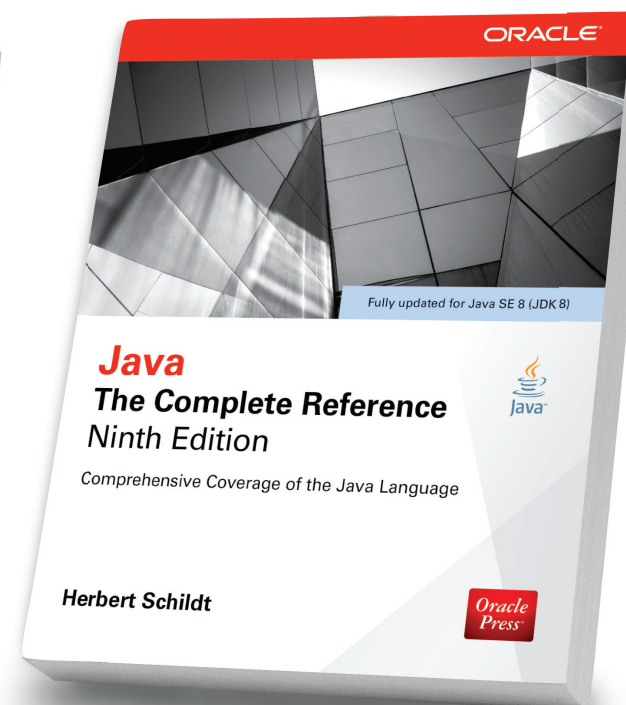
Use Raspberry Pi with Java to create innovative devices that power the internet of things.



**Introducing JavaFX 8
Programming**

Herbert Schildt

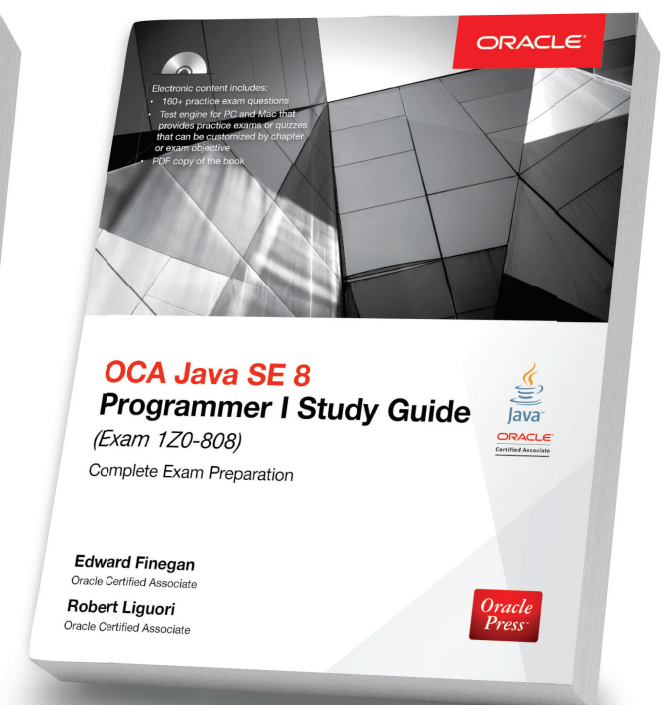
Learn how to develop dynamic JavaFX GUI applications quickly and easily.



**Java: The Complete Reference,
Ninth Edition**

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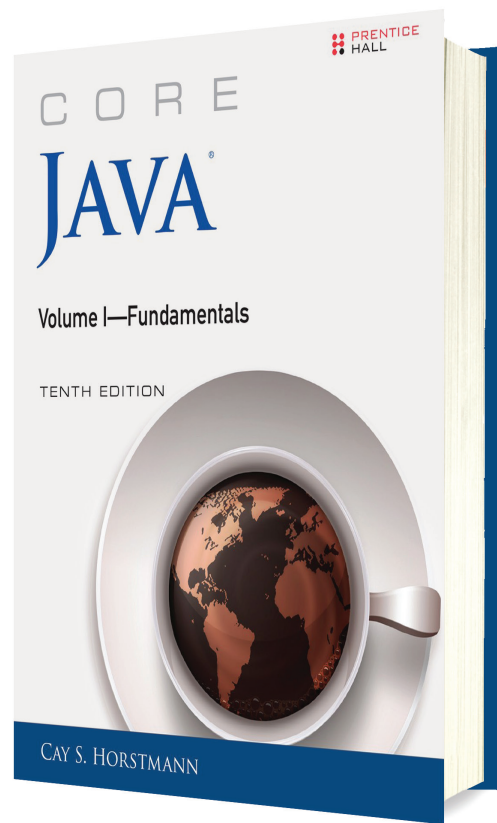
Fully updated for Java SE 8, this definitive guide explains how to develop, compile, debug, and run Java programs.



**OCA Java SE 8 Programmer I
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Edward Finegan, Robert Liguori

Get complete coverage of all objectives for Exam 1Z0-808. Electronic practice exam questions are included.



By Cay S. Horstmann
Prentice-Hall

A common question asked by developers new to Java is which book is the best introduction to the language. The answer really depends on what exactly they're looking for. If it's a detailed explanation of the language that explains every aspect and idiom and can serve as a reference later on, then the book to get is *Core Java*, which I review next. If, however, they would rather not work through hundreds of pages but would prefer a hands-on experience in which they write small programs that quickly teach the language in a series of graduated projects, then the latest entry in the *Murach's Beginning Java* series, which I examine in the second part of this review, is the book I recommend.

Core Java announces its historical success by noting that this volume is the *10th* edition. Not many books are popular enough to warrant the publisher

releasing 10 editions. But *Core Java* provides such a deep explanation of the language that most readers will want the book to be always close at hand. This tome, at an impressive 1,040 pages, is only Volume I of a two-volume set. (Volume II will be published shortly. If the division of coverage is similar to earlier editions, it will weigh in at about 1,000 pages as well.) Between the two books, there is no aspect of the language or its principal libraries that is not explained in detail.

Volume I presents everything a mainstream programmer will need to know about Java 8: the basics of the language (including generics, lambdas, and other advanced features), collections, concurrency, and, curiously, graphics programming with Swing. In addition, there is a lengthy section on building and deploying Java programs. (Volume II is scheduled to cover

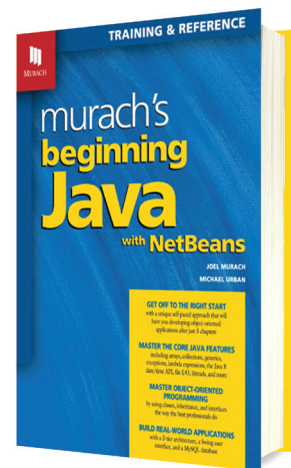
Java 8 streams, XML and JSON processing, JNI, JNDI, networking, databases and JDBC, and so on.) Essentially, Volume I is the pure language and Volume II is key libraries as well as lesser-used language features.

What makes *Core Java* the definitive work on the language is more than its vast scope—it is the quality of the presentation. Explanations are supremely clear, code examples are meticulous and highly approachable, and the pacing and sequencing are spot on. In addition, if a topic requires background to make the Java examples easier to understand, the author, the well-regarded Cay Horstmann, has no difficulty spending several pages on the conceptual issues before starting in on Java-specific details. This patience and his preference for complete information is particularly noticeable in the chapters that deal with Java objects. There

Horstmann first explains how Java implements object orientation, the choices and trade-offs it makes, and how those affect the way the language is written and used today. In these explanations (and many others), Horstmann relies on his long experience with the language. Using his background, he frequently explains how certain features are based in Java's early history and how the needs of the time informed the reasoning for various design choices. This kind of full, detailed information makes it much easier to understand subtle aspects of the language and use them as intended. (Note that if this much detail is more information than you're looking for in a language tutorial, Horstmann has an abridged version, *Core Java for the Impatient*, which weighs in at just over 500 pages. I reviewed this book in the May/June 2015 issue.)

I am a big fan of detailed language tutorials that can serve as definitive references once I've mastered the basics. No other book on Java better fits this mandate than *Core Java*. This has been true for at least the last 10 years, possibly longer. If you feel that the advent of Java 8 suggests it's time to update your language tutorial

and reference, then this is *the* book to get, without any doubt at all.



MURACH'S BEGINNING JAVA WITH NETBEANS

By Joel Murach and Michael Urban
Mike Murach & Associates

All Murach books, including this title, use a unique approach to instruction. They deliver a radical implementation of the notion that the best way to learn a new technology is to use it. So, rather than offering extensive tutorials that give you the full background information (as in the previously reviewed title), Murach books provide you only the material needed to master coding the immediate next step. These steps are typically presented in two-page chunks: the left page explaining the topic, the right page presenting the implementation in code,

with accompanying notes about the code itself. Turn the page, and you start a new two-page chunk. Needless to say, these short lessons build on each other so that after a chapter of them, you've done a fair amount of coding and have a working familiarity with the chapter's theme.

This is an entirely hands-on, pragmatic approach that works as follows, when explaining, for example, how to use arrays in Java. The topic comprises these two-page lessons: how to create an array, how to assign values to an array, how to use loops with arrays, how to use enhanced `for` loops with arrays, how to work with two-dimensional arrays, how to use the `Array` class, how to copy and compare arrays. Eighteen pages and you're good to go.

The benefit of this approach is obvious, and it makes the Murach books very attractive for teachers as well as for students who just want to get up and running quickly. The books also work as reference volumes. As can be seen from the previous list of topics, they can double as collections of useful, albeit elementary, recipes. (Notice the consistent use of "How to do x" as the template for each lesson.)

This hands-on design also

means that it's considerably easier to jump around and pick up the bits of knowledge you might need for solving a specific problem—without needing to learn the entire language. This approach works particularly well in Murach's books on HTML5 and CSS. It also works with languages, but not quite as well, because language features rarely can be studied in complete isolation.

While this volume is an introduction to the language, I feel that intermediate topics are given exposure that is too short. For example, in this volume, lambdas get only eight pages of coverage, which is plainly insufficient. To its credit, though, the book correctly identifies drawbacks of lambdas, which are rarely mentioned in other treatments: lambdas are difficult to debug, difficult to understand in a stack trace, and for those unfamiliar with them, difficult to understand in code.

This is *not* an introduction to programming with NetBeans; rather, it's a tutorial on Java that incidentally uses NetBeans. For teachers of Java boot camps or quick language intensives and for developers who need to get up and running quickly, this tutorial is the one to use. —Andrew Binstock



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Building Modern Web Apps

This issue of *Java Magazine* focuses on development of web apps. Had this issue appeared, say, two years ago, the content would have been completely different. In those days, the topic would have mandated extensive coverage of those innumerable Gordian knots of interconnected services, Java frameworks. But today, in this issue, we cover only one framework, Spring Boot (page 15). This is partly due to the fact that Spring has essentially won the framework wars (at least from the perspective of popularity and adoption), and to the fact that the nature of web apps has changed substantially. REST services have replaced in many ways the services delivered formerly by frameworks. As REST continues its ascendance, the role of the JAX-RS 2.0 spec (page 31) has become more important than ever.

Not all connections to remote servers, however, are suited to REST's simple commands. Some connections need to be long-lasting, and for this problem, there are at least two important solutions: the WebSocket protocol (page 47) as found in Java EE and the more widely supported long-polling approach (page 41), both of which are remarkably straightforward to use. If the greater use of simple services is the emerging pattern in web apps, it's also the emerging pattern at the metalevel. Large applications of all kinds—web or not—are being decomposed into smaller services, which are then orchestrated to deliver the intended functionality. This microservices orientation is being driven via the agility conferred by smaller containers such as Docker (page 72). And—ironically enough—new frameworks, such as KumuluzEE (page 80), are gaining traction to aid in this simplification.

Finally, for those of us working with tried-and-true JavaServer Faces (JSF), this issue includes a detailed overview and tutorial of OmniFaces (page 23), the wide-ranging JSF utility library that deservedly won the 2015 Duke's Choice Award.

ART BY I-HUA CHEN



First Steps with Spring Boot

Spring Boot is an opinionated way to quickly build web applications intended for production. It pulls together and integrates lots of technologies including Spring and Java EE. And it makes them accessible through a simple UI that enables you to mix and match components and quickly assemble the pieces, to which you then add your application's specific knowledge. This approach has gained popularity because it greatly reduces the amount of boilerplate code and housekeeping tasks. In this article, I show the steps involved in setting up a simple application that includes a modestly complex UI and a persistence layer. In addition, it contains tests—in the way that modern software development practices dictate.

There are many ways to get started with Spring Boot. My favorite is [Spring Initializr](#), which is a web service you can use directly or from wizards inside your favorite IDEs (NetBeans; IntelliJ IDEA 14 Ultimate; or the [Spring Tool Suite](#), which is an Eclipse distribution). Whatever your approach, in Spring Initializr you'll be shown a menu of checkboxes. Choose the type of workloads and technologies you'd like to work with.

This article looks briefly at lots of different technologies. The goal is to highlight just how easy it is to pull them together into a useful application. For our example, choose these technologies from the wizards: Web, JPA (the Java Persistence API), REST repositories, Vaadin (the UI library),

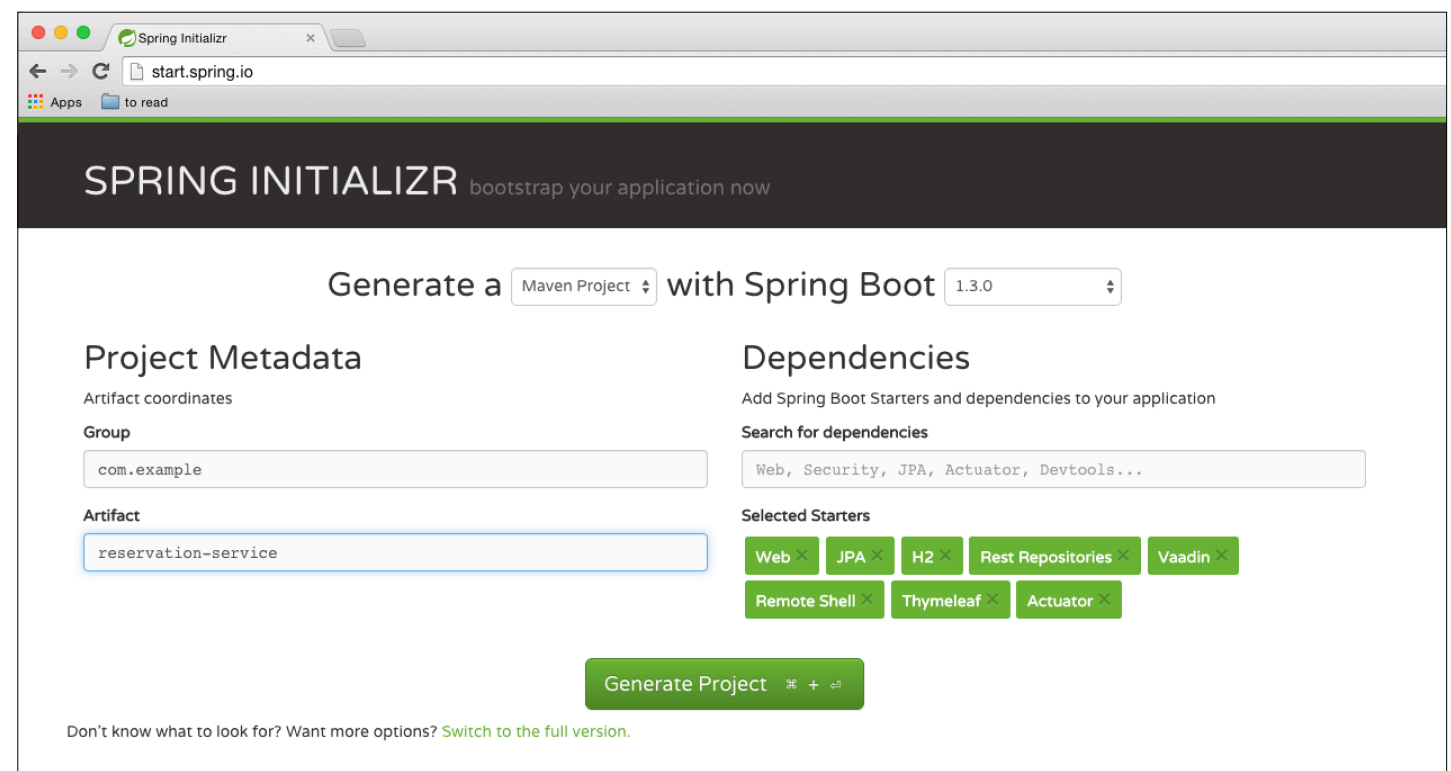


Figure 1. Selecting project options


```
@Entity
public class Reservation {

    @Id
    @GeneratedValue
    private Long id;

    private String reservationName;

    public Reservation(String reservationName) {
        this.reservationName = reservationName;
    }

    Reservation() {
    }

    @Override
    public String toString() {
        return "Reservation{" + "id=" + id +
            ", reservationName='" +
            reservationName + '\'' +
            '}';
    }

    public Long getId() {
        return id;
    }

    public String getReservationName() {
        return reservationName;
    }
}
```

The `Reservation` entity is trivial; it's just meant to demonstrate that we can use the full power of JPA. We'll use Spring Data JPA, one module of the larger Spring Data project, which features similar support for other persistence technologies such as Oracle Database, MongoDB, Neo4j, Cassandra, and others. It enables us to declaratively define a repository object,

based on interface method name conventions, such as this:

```
interface ReservationRepository extends
    JpaRepository<Reservation, Long> {

    Collection<Reservation>
        findByReservationName(String rn);
}
```

With this in place, we've also defined an `@Bean` provider method in the `ReservationServiceApplication` class. Because it's annotated with `@SpringBootApplication`, the `ReservationServiceApplication` class is also an `@Configuration` class where `@Bean` provider methods may live. Any `@Configuration` class may use defined beans as return values from provider methods. This is an alternative to annotating the component itself with stereotype annotations like `@Component`, `@RestController`, and so on. The returned object, of type `CommandLineRunner`, will be run when the Spring Boot application starts up. Therefore, this is an ideal place to insert some sample data for this demonstration:

```
@Bean
CommandLineRunner runner(ReservationRepository rr) {
    return args -> Stream.of(
        "Julia", "Mia", "Phil", "Dave", "Pieter",
        "Bridget", "Stéphane", "Josh", "Jennifer")
        .forEach(n -> rr.save(new Reservation(n)));
}
```

The Web

We can then create a REST API using Spring MVC (as well as the Jersey JAX-RS implementation or Ratpack, for which there are checkboxes in Spring Initializr). Here's our code:

```
@RestController
class ReservationRestController {
```



```

private final ReservationRepository
    reservationRepository;

@Autowired
public ReservationRestController(
    ReservationRepository reservationRepository){
    this.reservationRepository =
        reservationRepository;
}

@RequestMapping(method = RequestMethod.GET,
    value = "/reservations")
public Collection<Reservation>
    getReservations() {
        return
            this.reservationRepository.findAll();
    }
}

```

Bring up `http://localhost:8080/reservations` and you'll see the results returned in JSON, as in Figure 3.

This is a respectable first cut at a REST API, but what I really want to do is map the state transitions of my entities—turning creation, querying, deletion, and updates into HTTP verbs. So, let's remove the manual REST API we just created and instead let the `ReservationRepository` that we created earlier—which knows how to create, read, update, query, and delete `Reservation` entities—handle this for us with Spring Data REST.

We'll simply revise the repository code, adding the requisite `@RepositoryRestResource` and `@RestResource` annotations.

```

@RepositoryRestResource
interface ReservationRepository extends
    JpaRepository<Reservation, Long> {

    @RestResource(path = "by-name",
        rel = "by-name")

```

```

    Collection<Reservation> findByReservationName(
        @Param("rn") String rn);
}

```

Bring up `http://localhost:8080/reservations` again and you'll see the same information as before along with extra links. These links are metadata that are embedded in the resource response. They provide a *menu* of paths that a client may take that are related to the payload. You can add custom links using `ResourceProcessor` implementations. Scroll through the results. Each `Reservation` contains a link to itself, aptly named `self`. Scroll further and you'll see the links to the `search` resource, where you can find more links still, including one that exports our earlier custom finder method, `findByReservationName`, as a search resource. Now, without any a priori knowledge, a REST client can start at `/` and interactively navigate through the resources using the hypermedia (which in HTTP parlance refers to the previous links) provided by the links and the HTTP `OPTIONS` verb to understand what's possible.

Now, let's add some web application functionality. We'll stand up a Spring MVC controller that processes an HTTP



Figure 3. Returned results as a JSON file

request, establishes model data, and then forwards it to a Thymeleaf template for rendering.

```
@Controller
class ReservationMvcController {

    private final ReservationRepository
        reservationRepository;

    @Autowired
    public ReservationMvcController(
        ReservationRepository rr) {
        this.reservationRepository = rr;
    }

    @RequestMapping(method = RequestMethod.GET,
        value = "/reservations.mvc")
    public String renderReservations(Model model) {
        model.addAttribute("reservations",
            this.reservationRepository.findAll());
        // find template named 'reservations'
        return "reservations";
    }
}
```

A request to `http://localhost:8080/reservations.mvc` ultimately renders an HTML template in the `src/main/resources/templates` directory. It looks like this:

```
<!DOCTYPE HTML>
<html xmlns="http://www.w3.org/1999/xhtml"
      xmlns:th="http://www.thymeleaf.org">
<head>
    <title> Reservations </title>
</head>
<body>
<H1> Reservations </H1>
<div th:each="r : ${reservations}">
    <div>
        <b th:text="${r.id}">ID</b> -
```

```

        <span th:text="${r.reservationName}">
            Reservation Name
        </span>
    </div>
</div>
</body>
</html>

```

The result of this is shown in Figure 4.

Many applications might simply deliver REST APIs and serve a client-side JavaScript application that connects to those endpoints. The assets for such an application would live in the `src/main/resources/static` directory. They will not be processed.

If you're trying to build a data-driven user interface quickly, you might use a UI component-based approach such as the well-regarded, open source [Vaadin Framework](#). Earlier, I selected the **Vaadin** checkbox in Spring Initializr. That selection brings in a third-party dependency to support an easy Spring Boot integration with Vaadin. Vaadin builds on top of [GWT](#); UI components consist of fast, responsive transpiled client-side JavaScript. But in Vaadin apps, business state lives on the server. Here's a simple

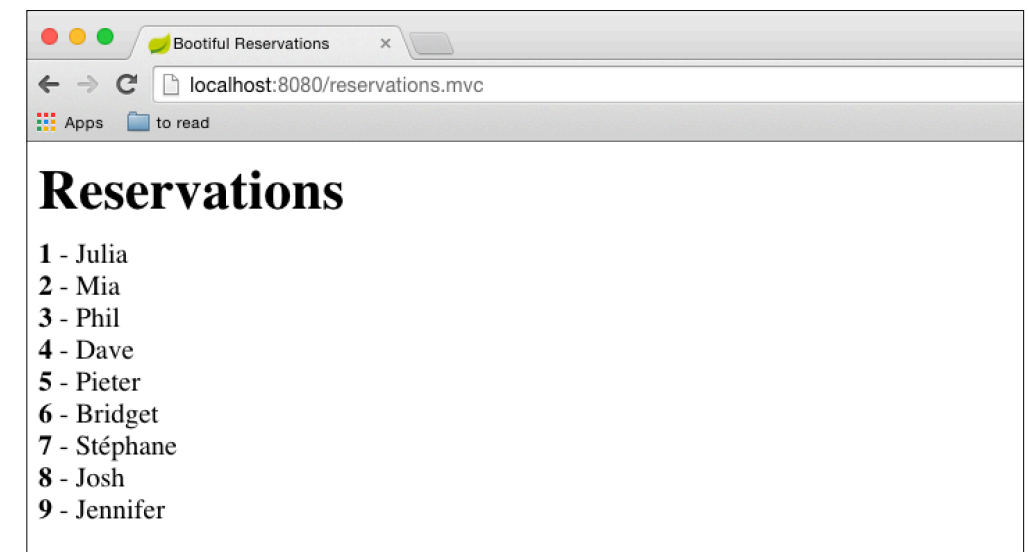


Figure 4. The reservations application so far

data grid to present the `Reservation` data, using Vaadin components.

```
@SpringUI(path = "ui")
@Theme("valo")
class ReservationUI extends UI {

    private final ReservationRepository
        reservationRepository;

    @Autowired
    public ReservationUI(ReservationRepository
        reservationRepository) {
        this.reservationRepository =
            reservationRepository;
    }

    @Override
    protected void init(VaadinRequest request) {
        Grid table = new Grid();
        BeanItemContainer<Reservation> container =
            new BeanItemContainer<>(
                Reservation.class,
                this.reservationRepository.findAll());
        table.setContainerDataSource(container);
        table.setSizeFull();
        setContent(table);
    }
}
```

And that's it! Run the application by going to `http://localhost:8080/ui` and you'll see the screen in Figure 5.

Testing

Naturally, we should test all the parts of the application. The Spring MVC test framework makes short work of exercising our HTTP endpoints, thanks to a fluid, built-in domain-specific language (DSL).

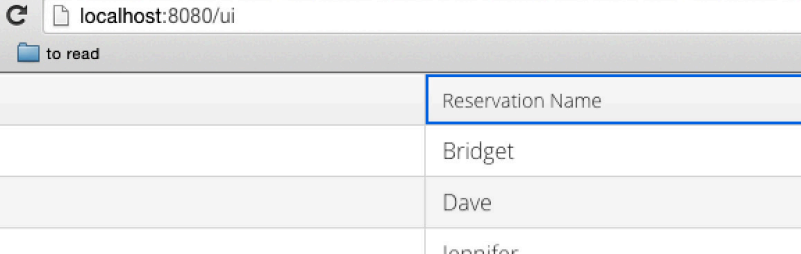
```
@RunWith(SpringJUnit4ClassRunner.class)
@SpringApplicationConfiguration(classes =
    ReservationServiceApplication.class)
@WebAppConfiguration
public class ReservationServiceApplicationTests {

    private MediaType mediaType =
        MediaType.parseMediaType(
            "application/hal+json");

    private MockMvc mockMvc;

    @Autowired
    private WebApplicationContext
        webApplicationContext;

    @Before
    public void before() throws Exception {
        this.mockMvc =
            MockMvcBuilders.webApplicationContextSetup(
                this.webApplicationContext).build();
    }
}
```



The screenshot shows a web browser window with the address bar displaying 'localhost:8080/ui'. The page content is a table with two columns: 'Id' and 'Reservation Name'. The table contains seven rows of data. The browser's address bar and navigation buttons are visible at the top.

Id	Reservation Name
6	Bridget
4	Dave
9	Jennifer
8	Josh
1	Julia
2	Mia
3	Phil
5	Pieter
7	Stéphane

Figure 5. The application using a UI library

```
@Test
public void contextLoads()
    throws Exception {
    this.mockMvc.perform(
        get("/reservations")
        .accept(this.mediaType))
        .andExpect(content().
            contentType(this.mediaType))
        .andExpect(status().isOk());
}
```

This code uses the Spring MVC test framework, which is a custom test runner that works with JUnit or TestNG. This test framework is ideal for pseudo integration tests. Here, I use it to stand up our Spring Boot application completely without actually connecting to a socket. The Spring MVC test framework dispatches calls through the whole Spring MVC machinery and actually exercises all the web components, but does so without sitting on a socket somewhere listening for actual TCP packets coming in as HTTP. This means that you don't have to stand up a container just to test the framework machinery or the components responsible for processing requests.

Production

The application is now interesting, but being interesting just isn't enough. We need to get the software deployed. If you've ever read Michael Nygard's excellent book, *Release It!*, then you know that the last mile between "code complete" and "production ready" can be a long mile indeed! Talk to enough organizations and you'll realize that there's a litany of nonfunctional requirements, usually buried in some wiki page somewhere, that each organization requires its applications to satisfy before code can be moved to production.

These aren't exciting things, either. They're not differen-

tiators. What does the application's environment look like? How do you capture growth metrics? Does your application provide an endpoint to answer questions about its health? How do you identify which version of the service is running? Which HTTP resources are exposed to traffic? These questions, and many more besides, are answered thanks to automatically created endpoints provided by the Spring Boot Actuator, which is a module in Spring Boot designed to support operationalizing applications for production. Spring Boot Actuator helps reduce or remove the list of nonfunctional requirements that commonly gate our ability to move code to production. It furnishes management endpoints such as `/health`, `/beans`, `/trace`, `/mappings`, `/metrics`, `/env`, and many more. These endpoints are useful and easily customized. Let's change the management endpoint's prefix with a property specified in the `application.properties` file, where, along with `application.yml`, Spring Boot will look to find configuration keys and values:

```
management.context-path=/admin
```

With this property, users will need to go to `/admin/health`, `/admin/env`, and so on. If I add `spring-boot-starter-security` to the CLASSPATH, I'll get the default HTTP BASIC authentication prompt with a default username and password that will be printed on the console. I can delegate the HTTP BASIC authentication challenge to a Spring Security AuthenticationProvider instead by configuring the appropriate Spring Security options.

The **health** endpoint is interesting, because it measures the health of the system. It automatically tells us whatever it can about the technologies in play. It knows about the file system, a **DataSource** connection pool, JavaMail, JMS, Cassandra, Elasticsearch, Solr, MongoDB, RabbitMQ, Redis, and many more technologies. We can augment this data with a semantic **HealthIndicator**, if we want to:

The kind of data it retrieves is shown in **Figure 6**.

The application automatically collects metrics for common things—for example, requested HTTP resource counts, how much memory is available, how many classes loaded, and so on. In addition, any component in the application can inject a

Figure 6. Data from monitoring the application's health

Running the application is easy, too. You can choose to use the self-contained JAR-based deployment by selecting Jar for the packaging in Spring Initializr. Or you can deploy into any servlet container such as Apache Tomcat/TomEE, Oracle WebLogic or GlassFish, Payara Micro, IBM WebSphere, or Red Hat's WildFly application server by selecting .war for the packaging in Spring Initializr. Modern cloud environments such as CloudFoundry, Heroku, Google App Engine, and OpenShift can also run Spring Boot applications.

This short tutorial has just barely scratched the surface. Spring Boot can integrate many other technologies, including many from Java EE: JAX-RS, JMS, the Servlet API, JTA, and JDBC, as well as all the components from the Spring ecosystem. It also provides the basis for Spring Cloud, which is a set of components designed to support the creation of distributed systems based on microservices. Spring Boot is an opinionated way to get going by leveraging default configurations for common tasks. These configurations are often defined and provided by the industry experts who lead the technologies being configured. To get the bits and start your journey, check out [Spring Initializr](#). </article>





ANGHEL LEONARD

OmniFaces: Making JSF a Lot Easier

Solve many day-to-day JSF problems with a single, integrated utility library.

Omnifaces is a utility library for JSF 2 developed by two members of the JSF Expert Group: Bauke Scholtz and Arjan Tijms. Its main purpose is to give JSF developers a solution for day-by-day JSF-related problems and questions. OmniFaces can be used in both JSF implementations, [Mojarra](#) and [MyFaces](#), and it works with existing JSF libraries (such as [PrimeFaces](#), [RichFaces](#), [ICEfaces](#), [OpenFaces](#), and others). In previous writing, I defined OmniFaces as “a utility library for JSF and a comprehensive compendium of programming techniques, design patterns and recipes for JSF developers.” [OmniFaces won a 2015 Duke’s Choice Award from the Java community. —Ed.]

The OmniFaces project started in March 2012, and the first release (OmniFaces 1.0) took place on June 1 of that year. The latest stable release is OmniFaces 2.2, released in late 2015. According to the [project founders](#), the original motivation for the library was that the lead developers realized they each had built libraries of routines that covered the same problems and that they had separate but similar libraries they’d developed at work. It occurred to them that a single, integrated library with no duplication of solutions would be ideal. This led to OmniFaces. Currently, OmniFaces is on the road to version 2.3 and, in the future, to version 3.0.

What Does OmniFaces Offer?

Today OmniFaces offers a significant number of utility components, validators (including cross-field validation), converters, resource handlers, view handlers, tag handlers, exception

handlers (such as an Ajax exception handler), extensionless URL support, event listeners, CDI artifacts (for example, view scope, cookie and init parameters injection, and eager beans), and so on. In addition, it contains more than 300 utility methods and functions. Via these utilities, your JSF code will become less verbose, more loosely coupled, cleaner, and easier to debug. Everything is available for testing (live demo) in the [OmniFaces Showcase](#).

Table 1 gives a quick overview of the contents and abilities of OmniFaces. While using OmniFaces components, you can develop new families of components, extend existing components, suppress or add specific functionality, write custom renderers, and perform other useful actions.

In addition to the capabilities shown here, OmniFaces ships with features that support CDI, FacesViews, filters, managed beans, render kits, scripts, and functions.

How OmniFaces Differs from Other JSF Libraries

To understand the difference, it is important to understand the niche that OmniFaces occupies among the JSF libraries. In **Figure 1**, you can see the location of OmniFaces on the JSF map.

OmniFaces is not in the same category as PrimeFaces, RichFaces, or BootsFaces. While PrimeFaces and RichFaces can be considered mutually exclusive, this is not the case with OmniFaces. Because it is a utility library, it can be employed with or without PrimeFaces, RichFaces, and BootsFaces, rather than as an alternative to these libraries.



COMPONENTS (PARTIAL LIST).	
Cache	A SERVER-SIDE CACHE OF RENDERED MARKUP
GraphicImage	LOADS IMAGES FROM <code>byte[]/InputStream/SVG</code> (OPTIONAL AS DATA URI)
Tree	PROVIDES FULL CONTROL OVER THE MARKUP OF A TREE HIERARCHY
CommandScript	GENERATES A JAVASCRIPT FUNCTION IN THE GLOBAL JAVASCRIPT SCOPE
DeferredScript	DEFERS THE LOADING OF THE GIVEN SCRIPT RESOURCE TO THE WINDOW LOAD EVENT
Form	KEEPS VIEW OR REQUEST PARAMETERS IN THE REQUEST URL AFTER A POST-BACK
IgnoreValidationFailed	IGNORES VALIDATION FAILURES (INVOKE ACTION PHASE WILL BE EXECUTED ANYWAY)
Highlight	HIGHLIGHTS ALL INVALID <code>UIInput</code> COMPONENTS AND THE ASSOCIATED LABELS
Messages	MULTIPLE <code>for</code> OPTIONS, SINGLE MESSAGE, HTML ESCAPING, ITERATION MARKUP CONTROL
VALIDATORS (TO WRITE A MESSAGE INTERPOLATOR AND CROSS-FIELD VALIDATORS, WHICH ARE NOT SUPPORTED BY DEFAULT IN JSF).	
<code>JsfLabelMessageInterpolator</code>	ALLOWS A LABEL TO APPEAR IN THE MIDDLE OF A BEAN VALIDATION MESSAGE
<code>RequiredCheckboxValidator</code>	SOLVES THE <code>required="true"</code> ATTRIBUTE AND <code>UISelectBoolean</code> ISSUE
<code>ValueChangeValidator</code>	VALIDATES ONLY WHEN THE SUBMITTED VALUE IS REALLY CHANGED
<code>validateAll</code>	VALIDATES IF ALL <code>UIInputs</code> HAVE BEEN FILLED OUT
<code>validateAllOrNone</code>	VALIDATES IF ALL OR NONE OF THE <code>UIInputs</code> HAVE BEEN FILLED OUT
<code>validateEqual</code>	VALIDATES IF ALL <code>UIInputs</code> HAVE THE SAME VALUE
<code>validateMultiple</code>	VALIDATES MULTIPLE FIELDS BY A CUSTOM VALIDATOR METHOD
<code>validateBean</code>	PROVIDES BEAN VALIDATION ON A PER- <code>UICommand/UIInput</code> COMPONENT BASIS, AS WELL AS VALIDATING A GIVEN BEAN AT THE CLASS LEVEL
EXCEPTION HANDLERS (ESPECIALLY POWERFUL FOR CAPTURING AND TREATING “SILENT” EXCEPTIONS IN A FRIENDLY MANNER).	
<code>FacesMessageExceptionHandler</code>	ADDS EVERY EXCEPTION AS A GLOBAL FATAL FACES MESSAGE
<code>FullAjaxExceptionHandler</code>	HANDLES AS NON-AJAX EXCEPTIONS ANY EXCEPTIONS THAT OCCUR DURING AJAX REQUESTS
CONTEXTS.	
<code>OmniPartialViewContext</code>	EXTENDS AND IMPROVES THE STANDARD PARTIAL VIEW CONTEXT

Table 1. List of principal components and handlers in OmniFaces (continued on next page)

Including OmniFaces in JSF Applications

OmniFaces can be added in a JSF application as a JAR file or as a Maven dependency. Practically, it is merely a matter of putting the OmniFaces JAR file into the `/WEB-INF/lib` directory.

Maven users can add OmniFaces by adding the corresponding Maven coordinates to the `pom.xml` file. In the following example, I have added the dependency for OmniFaces 2.2:

```
<dependency>
  <groupId>org.omnifaces</groupId>
  <artifactId>omnifaces</artifactId>
  <version>2.2</version>
</dependency>
```

In the JSF application below, I've added it just ahead of the PrimeFaces library and Java EE 7:

```
<dependencies>
  <dependency>
    <groupId>org.omnifaces</groupId>
    <artifactId>omnifaces</artifactId>
    <version>2.2</version>
  </dependency>
  <dependency>
    <groupId>org.primefaces</groupId>
    <artifactId>primefaces</artifactId>
    <version>5.2</version>
  </dependency>
  <dependency>
    <groupId>javax</groupId>
    <artifactId>javaee-api</artifactId>
    <version>7.0</version>
    <type>provided</type>
  </dependency>
</dependencies>
```

TAG HANDLERS.	
converter	PROVIDES SUPPORT FOR DEFERRED VALUE EXPRESSIONS IN ALL CONVERTER ATTRIBUTES
RestorableView	RE-CREATES THE ENTIRE VIEW WHENEVER THE VIEW HAS BEEN EXPIRED
importConstants	MAPS CONSTANTS OF THE GIVEN FQN OF A TYPE IN THE REQUEST SCOPE
importFunctions	MAPS FUNCTIONS OF THE GIVEN FQN OF A TYPE IN THE "FACELET SCOPE"
validator	PROVIDES SUPPORT FOR DEFERRED VALUE EXPRESSIONS IN ALL VALIDATOR ATTRIBUTES
viewParamValidationFailed	HANDLES VIEW PARAMETER VALIDATION FAILURE VIA REDIRECT OR HTTP ERROR CODE
CONVERTERS (THESE ADVANCED CONVERTERS CLOSE GAPS IN JSF).	
ListIndexConverter	PERFORMS CONVERSION BASED ON THE POSITION (INDEX) OF THE SELECTED ITEM IN THE LIST
ListConverter	WORKS DIRECTLY VIA A List OF ENTITIES (CANNOT USE ListIndexConverter)
SelectItemsConverter	AUTOMATICALLY CONVERTS <f:selectItems> ENTITIES
SelectItemsIndexConverter	SAME AS SelectItemsConverter, BUT DOES CONVERSION BASED ON THE POSITION (INDEX)
ValueChangeConverter	DOES CONVERSION ONLY WHEN THE SUBMITTED VALUE HAS CHANGED
GenericEnumConverter	USED IN UISelectMany COMPONENTS WHOSE VALUE HAS BEEN BOUND TO A List<E> PROPERTY WHERE E IS AN ENUM
RESOURCE HANDLERS (HANDLING CDNS, MULTIPLE RESOURCES IN A SINGLE CALL, AND SO ON).	
CDNResourceHandler	PROVIDES CDN URLS INSTEAD OF THE DEFAULT LOCAL URLS FOR JSF RESOURCES
CombinedResourceHandler	CREATES A COMBINED RESOURCE FOR ALL SCRIPTS AND ONE FOR ALL STYLESHEETS
UnmappedResourceHandler	MAPS JSF RESOURCES ON A URL PATTERN OF /javax.faces.resource/*
EVENT LISTENERS.	
InvokeActionEventListener	WORKS WITH NEW <f:event> TYPES preInvokeAction AND postInvokeAction
ResetInputAjaxActionListener	RESETS INPUT FIELDS THAT ARE NOT EXECUTED DURING AN AJAX SUBMIT, BUT WHICH ARE RENDERED/UPDATED DURING AN AJAX RESPONSE
VIEW HANDLERS (A USEFUL AND CORRECT USE CASE FOR VIEW HANDLERS).	
NoAutoGeneratedIdViewHandler	DOESN'T ALLOW AUTO-GENERATED IDS (j_id AND SO ON)

Table 1. List of principal components and handlers in OmniFaces (continued from previous page)

For OmniFaces SNAPSHOTS, the numbering pattern is *major_version.minor_version*-SNAPSHOT:

```
<dependency>
  <groupId>org.omnifaces</groupId>
  <artifactId>omnifaces</artifactId>
  <version>2.3-SNAPSHOT</version>
</dependency>
```

Note: Users of outdated environments who can't or won't use CDI should use OmniFaces version 1.11 instead. It doesn't contain anything from CDI, so while it works, it doesn't offer OmniFaces' full range of solutions.

The OmniFaces artifacts are available in the following XML namespaces:

```
xmlns:o="http://omnifaces.org/ui"
xmlns:of="http://omnifaces.org/functions"
```

Using OmniFaces

Probably, the best way to demonstrate OmniFaces artifacts is to explore several examples. For the rest of this article, I'll solve common problems of JSF applications by using OmniFaces. Additional examples can be found [here](#).

Combine script and stylesheet resources to improve page loading. As a JSF developer, you should be familiar with the mechanism of loading resources in JSF. Basically, for each resource, JSF will fire a separate GET request. This is a time-consuming task, especially if there is a large number of resources to load.

The [OmniFaces CombinedResourceHandler](#) considerably improves page loading. This is



achieved by removing from the `UIWebViewRoot` all the separate script and stylesheet resources that have the target attribute set to "head" and combining them for all scripts (and separately combining them for all stylesheets). So, instead of firing a GET request per resource, the browser will fire a single GET request for all scripts and another one for all stylesheets. Further, the `CombinedResourceHandler` is responsible for sequentially returning all the resources combined in these requests.

Visually speaking, something like this:

```
<!-- stylesheets -->
<h:outputStylesheet name="css/style.css" />
<h:outputStylesheet name="css/page.css" />
...

<!-- scripts -->
<h:outputScript library="default"
    name="js/my_js.js" target="head"/>
<h:outputScript library="custom"
    name="js/custom1.js" target="head"/>
<h:outputScript library="custom"
```

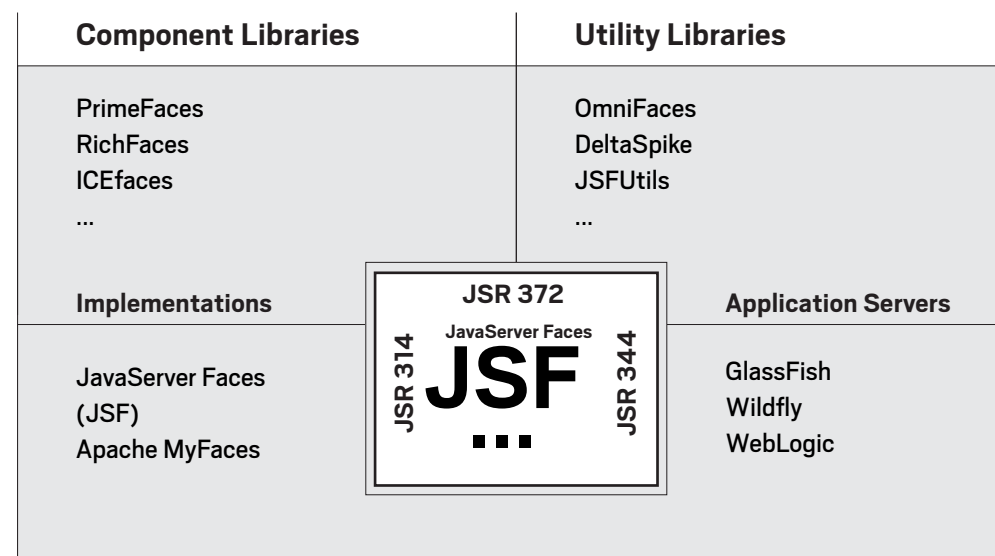


Figure 1. Where OmniFaces fits

```
name="js/custom2.js" target="head"/>
...

<!-- deferred scripts -->
<o:deferredScript library="default"
    name="js/js2.js"/>
<o:deferredScript library="default"
    name="js/js2.js"/>
...
```

becomes this:

```
<!-- for stylesheets -->
<link type="text/css" rel="stylesheet"
href="/MyApp/faces/javax.faces.resource/...css?
ln=omnifaces.combined&v=1433659201062" />

<!-- for scripts -->
<script type="text/javascript"
src="/MyApp/faces/javax.faces.resource/...js?
ln=omnifaces.combined&v=1433659204389">

<!-- for deferred scripts -->
<script type="text/javascript">
OmniFaces.DeferredScript.add(
    '/MyApp/faces/javax.faces.resource/...js?
    ln=omnifaces.combined&v=1433659201450');
</script>
```

[The ... in these resources indicates an app-specific string of characters, removed for legibility. —*Ed.*]

To get it to run, this handler needs to be registered, as follows, in `faces-config.xml`:

```
<application>
<resource-handler>
org.omnifaces.resourcehandler.CombinedResource
Handler
```

```
</resource-handler>
</application>
```

More details about configuring this handler are available in the [OmniFaces Showcase](#). You might also be interested in [CDNResourceHandler](#) and [UnmappedResourceHandler](#).

The select-items converter saves you from writing custom converters for UISelectItems. Typically, `<f:selectItems>` (or `UISelectItems`) points to a collection that provides the selectable items with values (objects), which can be instances of `SelectItem` or any other Java object. These instances are then encapsulated by JSF in `SelectItem` instances.

To render each selectable item, JSF uses a string representation of the selectable item's value (for example, it might invoke the `toString()` method of the object). While the rendering process of the selectable items works smoothly, the conversion of the submitted strings to corresponding values can be accomplished only if we indicate a custom converter, which might need to do the job based on possibly expensive service/DAO operations.

This problem is solved by OmniFaces, which provides a general custom converter ([SelectItemsIndexConverter](#)) capable of automatically converting the submitted strings to corresponding values based on the position of the submitted string (index) in the list of values.

In order to exemplify this case, first we need the base object (**value**). Let's use **Player**:

```
public class Player implements Serializable {

    private Long id;
    private String name;
    private String residence;
    private int age;

    // constructor with id, name, residence and age
}
```

```
// getter and setter
// override equals() and hashCode()
}
```

A managed bean contains a `List<Player>`:

```
@Named
@ViewScoped
public class PlayerBean implements Serializable {
    private static final long serialVersionUID = 1L;
    private Player selected;
    private List<Player> topfive;
    ...
    // populate the list
    // getters and setters
}
```

Finally, we expose to the user the `List<Player>` via a selection component (such as `<h:selectOneMenu>`):

```
<h:form>
  <h:outputLabel for="atp" value="Players: " />
  <h:selectOneMenu id="atp"
    value="#{playerBean.selected}">
    <f:selectItem itemLabel="Choose player"
      noSelectionOption="true" />
    <f:selectItems value="#{playerBean.topfive}"
      var="t" itemLabel="#{t.name},#{t.age}"
      itemValue="#{t}" />
  </h:selectOneMenu>
  <h:commandButton value="Select"/>
</h:form>
```

```
Selected: <h:outputText
    value="#{playerBean.selected.name},
    #{playerBean.selected.age}"/>
```


Normally, at this point you must write a custom converter especially for this case only, but OmniFaces provides a general custom converter named `SelectItemsIndexConverter`. Once you specify this converter (via `omnifaces.SelectItemsIndexConverter`), it automatically converts the submitted strings into the corresponding values (objects):

It's simple to use, isn't it? In addition, OmniFaces provides an alternative to this approach, which converts the submitted strings to corresponding values based on the `toString()` implementation of those values. This [converter](#) uses the ID `omnifaces.SelectItemsConverter`.

The OmniFaces `tree` component provides a powerful and extremely versatile hierarchical tree structure solution that can be obtained via a `TreeModel` (with default implementa-

Let's see a simple example, and let's start with the model. `TreeBean` uses `ListTreeModel`, which is a `TreeModel` implementation that holds the tree children in an `ArrayList`:

28

```
// getter
}
```

In a JSF page, the `<o:tree>` does the work:

```
...
<o:tree value="#{treeBean.tree}" var="t">
  <o:treeNode>
    <ul>
      <o:treeNodeItem>
        <li>
          #{t}
          <o:treeInsertChildren />
        </li>
      </o:treeNodeItem>
    </ul>
  </o:treeNode>
</o:tree>
...
```

The output is shown in Figure 2.

The full application is available in the Tree app in the [downloadable code](#).

Use the full Ajax exception handler. Starting with JSF 2, there is a generic API that enables developers to write a global exception handler. This is very helpful, especially when we need to signal “silent” exceptions (such as Ajax exceptions) that are not reported to the user or are reported in a very discreet manner. As you probably know, exceptions that occur during Ajax requests are not treated the same as exceptions that occur during non-Ajax requests. By default, most of them are invisible to the client. Because users do not receive any feedback about the success of Ajax requests, users might become confused and restart the application, resend the request, or take other actions.

The OmniFaces [FullAjaxExceptionHandler](#) enables developers to handle exceptions that occur during Ajax

requests by using error pages configured in `web.xml` (or `web-fragment.xml`). To exploit the `FullAjaxExceptionHandler`, we need to explicitly configure the `FullAjaxExceptionHandlerFactory` in `faces-config.xml`.

```
<factory>
  <exception-handler-factory>
    org.omnifaces.exceptionhandler
      .FullAjaxExceptionHandlerFactory
  </exception-handler-factory>
</factory>
```

[In the snippet above, lines 3 and 4 should be entered as a single line. —*Ed.*]

It is good practice to provide at least a fallback error page whenever there is no match with any of the declared specific exceptions. Now, Ajax exceptions will not occur imperceptibly for the user, because they will be reported in the configured error page. The user will now know that something went wrong via messages in the error page and can act accordingly. So, you must at least have either

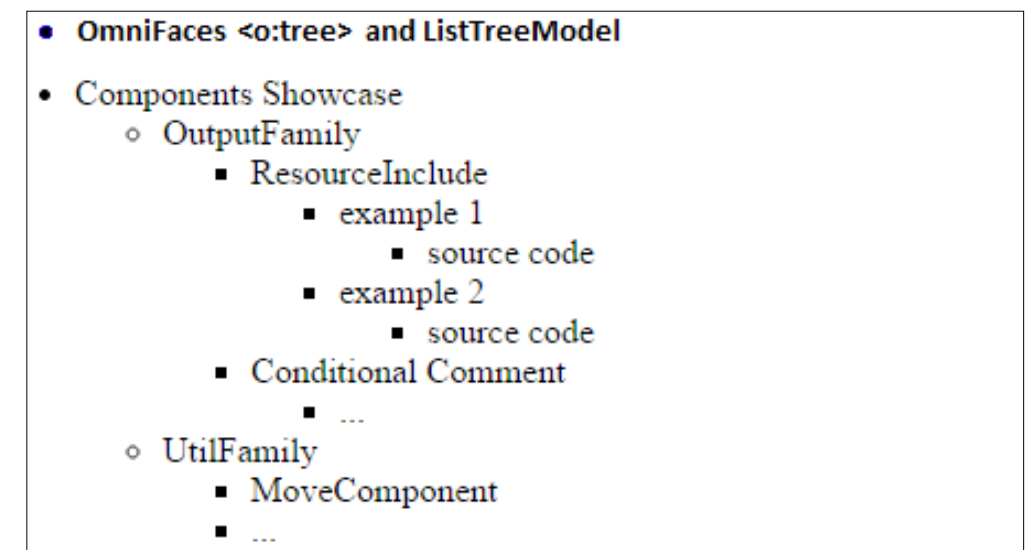


Figure 2. Simple tree output

```
<error-page>
  <error-code>500</error-code>
  <location>/WEB-INF/errorpages/500.xhtml
</location>
</error-page>
```

or this:

```
<error-page>
  <exception-type>java.lang.Throwable
</exception-type>
  <location>/WEB-INF/errorpages/500.xhtml
</location>
</error-page>
```

Reference an image provided as an `InputStream`, `byte[]`, or `data URI`. Most JSF novices know how to use the built-in `<h:graphicImage>` tag with the `name` and `library` attributes to load an image from the well-known `/resources` folder or from an external URL using the `value` or `url` attributes. (If not, check out [this article](#).) But what should be done when the image is not present at the end of a URL, for example, when it comes from a database, a web service, or a WebSocket? In such cases, the image usually comes as a byte array, `InputStream`, `BLOB`, or other form. In fact, what about an image as a data URI?

OmniFaces provides the `GraphicImage` component, which is an elegant solution for loading an image that comes as a byte array or `InputStream`, and it is capable of extracting a data URI also. The content type will be guessed based on the content header (it supports the JPEG, PNG, GIF, ICO, SVG, BMP, and TIFF formats). In addition, OmniFaces supports a “last modified” time stamp, which improves browser caching. In addition, SVG images can be loaded via modes, including the ability to show only a part of an SVG image (via `viewBox`). There are many examples of displaying images provided from an external resource, such as a serv-

let, that can be handled elegantly by OmniFaces.

Deal with a ViewExpiredException. A common issue in JSF consists of dealing with a `ViewExpiredException`. When a user session expires (such as when a session times out, a logical view was removed from the logical views map, or a session was programmatically invalidated), a `ViewExpiredException` occurs.

OmniFaces provides a tag handler named [EnableRestorableView](#), which is capable of “swallowing” a `ViewExpiredException` and restoring the view. I am here talking about session *restoring*, not about session *recovery*, which is a different challenge in JSF.

This tag handler can be used in a page by placing the `<o:enableRestorableView/>` tag in `<f:metadata>`. This allows us to instruct the view handler to re-create the entire view whenever the view has been expired. You simply write it like this:

```
<f:metadata>
<o:enableRestorableView/>
</f:metadata>
```

Conclusion

OmniFaces contains many other useful artifacts for JSF developers. In this article, you saw just a small part of what OmniFaces is capable of. As development continues, OmniFaces is becoming a more mature and powerful JSF utility library, thanks to the work of Bauke Scholtz and Arjan Tijms, who scan the JSF community for newly reported issues to solve. In this way, OmniFaces is always up to date on current issues. As expected, OmniFaces is open source under the Apache License 2.0. Enjoy! [</article>](#)

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JAX-RS 2.0: Using All the Goodness

The JAX-RS framework is a set of APIs for building applications and services that implement RESTful principles. It provides a simple yet powerful programming model in which plain old Java objects (POJOs) can be decorated with annotations to expose their services and some of the business logic over HTTP, the ubiquitous web protocol.

with HTTP-oriented (REST) services. The client API (part of the `javax.ws.rs.client` package) is fairly compact, lean, and fluent. Let's look at some of its classes and interfaces.

Some of the widely used JAX-RS implementations are [Jersey](#) (which is also the reference implementation), [RESTEasy](#), and [Apache CXF](#). All these implementations provide additional useful features beyond basic JAX-RS specification compliance and support.

```
graph LR; ClientBuilder[ClientBuilder] --> Client[Client]; Client --> WebTarget[WebTarget]; WebTarget --> InvocationBuilder[Invocation.Builder]; InvocationBuilder --> Invocation[Invocation];
```

The diagram illustrates the Builder pattern for a web client. It consists of five main components represented by colored rounded rectangles: **ClientBuilder** (blue), **Client** (green), **WebTarget** (light blue), **Invocation.Builder** (orange), and **Invocation** (red). The process flow is as follows: **ClientBuilder** builds a **Client** object, which then builds a **WebTarget** with a target URI. The **WebTarget** configures URI parameters and initiates the request building process, leading to the creation of an **Invocation.Builder**. Finally, the **Invocation.Builder** specifies the HTTP method and auxiliary properties to create the **Invocation** object.

A Brand-New Client API

Prior to the addition of a full-fledged client API, developers had to resort to using third-party implementations or interacting with the `URLConnection` API in the JDK to interact

and so on. This is made possible using the overloaded versions of the `register` method, which I'll discuss shortly. Note that this API is applicable to server-side JAX-RS components (filters, interceptors, and so on) as well.

Filters

Filters and interceptors (discussed later) are another big-ticket feature in JAX-RS 2.0. They provide aspect-oriented programming (AOP)-like capabilities within JAX-RS applications and enable developers to implement cross-cutting, application-specific concerns, which ideally should not be sprinkled all over the business logic. These capabilities include authentication, authorization, request/response validation, logging, and so forth. The AOP-based programming model involves interposing in methods of JAX-RS resource classes and dealing with (or mutating) components of HTTP request/response headers, request URIs, and the invoked HTTP method (GET, POST, and the others).

Server-side request filters. Server-side request filters act on incoming HTTP requests from the clients. They are called prior to JAX-RS resource method invocation, thus providing an opportunity to act on certain characteristics of the incoming HTTP requests.

To implement a server-side request filter, implement the `javax.ws.rs.container.ContainerRequestFilter` interface, which is an extension provided by JAX-RS. An instance of the `javax.ws.rs.container.Container`

Server-side response filters are similar to their counterpart (request filters) in terms of their utility (the read and mutate aspects of the response, for example, HTTP headers) and the programming model (for example, being executed as a chain in a user-defined or default order).

`RequestContext` interface is seamlessly injected by the container into the `filter` method of `ContainerRequestFilter`. It is a mutable object (on purpose) and exposes methods to access and modify HTTP request components.

```
public interface ContainerRequestFilter{
    public void filter(
        ContainerRequestContext reqCtx) throws
        IOException;
}
```

A JAX-RS request-processing pipeline involves dispatching an HTTP request to the appropriate Java method in the resource classes based on a matching algorithm implemented by the JAX-RS provider. Server-side request filters take this into account and are divided into two categories: prematching and postmatching.

Prematching filters are executed before the incoming HTTP request is mapped/dispatched to a Java method. A prematching filter can be configured easily by using the `javax.ws.rs.container.PreMatching` annotation on the class. Note that the `javax.ws.rs.ext.Provider` annotation on the implementation class, as shown next, is required for the JAX-RS runtime to recognize the filter as a JAX-RS filter.

```
@Provider
@PreMatching
public class PreMatchingAuthFilter{
    public void filter(
        ContainerRequestContext reqCtx)
        throws IOException {
        if(reqCtx.getHeaderString(
            "Authorization") == null){
            reqCtx.abortWith(
                Response.status(403).build());
        }else{
            //check credentials....
        }
    }
}
```

:

Postmatching filters are executed by the JAX-RS container only after the completion of the method dispatch/matching process. Unlike prematching filters, these filters do not need an explicit annotation. As a result, filter classes without the `@PreMatching` annotation are assumed to be postmatching by default. The following code shows an example in use:

```
@Provider
public class PostMatchingFilterExample{
    public void filter(ContainerRequestContext reqCtx)
        throws IOException{
        System.out.println(
            "Referrer: " +
            reqCtx.getHeaderString("referrer"));
        System.out.println(
            "Base URI: "+
            reqCtx.getUriInfo().getBaseUri());
        System.out.println(
            "HTTP Request method: "+
            reqCtx.getMethod());
    }
}
```

A JAX-RS application can have multiple filters (forming a chain-like structure), which are executed in a developer-defined order (more on this shortly) or in a default container-driven order. However, it is possible to break the chain of processing by throwing an exception from the filter implementation logic or by calling the `abortWith` method. In either case, the subsequent filters in the chain are not invoked.

Server-side response filters. A server-side response filter is invoked by the runtime after a response is generated by the JAX-RS resource method before dispatching the response to the caller/client. Response filters are similar to their counterpart (request filters) in terms of their utility (the read and

mutate aspects of the response—for example, HTTP headers) and the programming model (for example, being executed as a chain in a developer-defined or default order).

Setting up a server-side response filter is as simple as providing an implementation for the `javax.ws.rs.container.ContainerResponseFilter` interface. Just like its server-side request counterpart, the injection of `ContainerResponseContext` into the filter method of the `ContainerResponseFilter` interface is taken care of by the JAX-RS runtime. Server-side response filters also need to be annotated with the `javax.ws.rs.ext.Provider` annotation in order for the JAX-RS runtime to recognize them. An example of this follows:

```
@Provider
public class AContainerResponseFilter{
    public void filter(
        ContainerRequestContext reqCtx,
        ContainerResponseContext resCtx)
        throws IOException{
        //adding a custom header to the response
        resCtx
            .getHeaders()
            .add("X-Search-ID",
                "qwer1234-tyuio5678-asdfg9876");
    }
}
```

Client-side filters, predictably, include request and response filters, which I'll quickly summarize.

Client-side request filters. These are invoked after the HTTP request has been constructed but prior to the request being dispatched to the server. This type of filter provides an opportunity to mutate the properties of the HTTP request (such as headers and cookies). To implement a client-side request filter, implement the extension interface provided by `javax.ws.rs.client.ClientRequestFilter`.

Client-side response filters. Client-side response filters are invoked after the HTTP response has been received from the server but before it is dispatched to the caller/client for processing. Like client-side request filters, these filters provide an opportunity to mutate the properties of the HTTP response. To use a client-side response filter, implement the extension interface provided by `javax.ws.rs.client.ClientResponseFilter`, as shown next.

```
public class ClientResponseLoggerFilter {
    public void filter(
        ClientRequestContext reqCtx,
        ClientResponseContext resCtx)
        throws IOException{
        System.out.println(
            "Response status: " +
            resCtx.getStatus());
    }
}
```

Interceptors

Interceptors are similar to filters in the sense that they are also used to mutate HTTP requests and responses, but the major difference lies in the fact that interceptors are used primarily to manipulate HTTP message payloads. They are divided into two categories, `javax.ws.rs.ext` `.ReaderInterceptor` and `javax.ws.rs.ext` `.WriterInterceptor`, which are used to process HTTP requests and responses, respectively. Note that, unlike filters, the same set of interceptors is applicable on the server side and the client side.

Server-side interceptors need to be annotated with `@Provider` for the JAX-RS runtime to detect them. Client-side interceptors need to be registered with `ClientBuilder`, `Client`, or `WebTarget` class or interface (using the `register` method).

class or method. If it is applied to a class, the filter or interceptor will be bound to all the resource methods of the class.

```
@GET
@Path("/{id}")
@Produces("application/json")
@Audited
public Response find(
    @PathParam("id") String custId){
    //search and return customer info
}
```

Dynamic binding. JAX-RS provides the `DynamicFeature` interface to help bind filters and interceptors dynamically at runtime. (They can be used in tandem with the more static way of binding, which is made possible by using the `@NameBinding` annotation just discussed.)

```
public interface DynamicFeature {
    public void configure(
        ResourceInfo resInfo,
        FeatureContext ctx);
}
```

The injected instance of the `ResourceInfo` interface helps you choose the resource method in a dynamic fashion by exposing various methods, and the `FeatureContext` interface allows you to register the filter or interceptor once the resource method has been selected. The following code shows an example:

```
@Provider
public class DynamicAuthFilterFeature
    implements DynamicFeature {
    @Override
    public void configure(
        ResourceInfo resInfo, FeatureContext ctx) {
        if (UserResource.class
            .equals(resInfo.getResourceClass())) &&
```

```
resInfo.getResourceMethod().getName()
    .contains("PUT")) {
    ctx.register(
        AuthenticationFilter.class);
}
}
}
```

Binding and Registering Client-Side Filters and Interceptors

We saw that a (class-level) `@Provider` annotation is required for server-side filters. On the client side, filters and interceptors are registered using `ClientBuilder`, `Client`, or `WebTarget` interfaces, all of which implement the `javax.ws.rs.core.Configurable` interface, which provides multiple overloaded versions of the `register` method.

Ordering Filters and Interceptors

The `@Priority` annotation can be used to define the order of execution of filters and interceptors. It accepts a numerical value that is interpreted differently by request and response filters and interceptors.

The request filters (`ContainerRequestFilter` and `ClientRequestFilter`) and interceptors (`ReaderInterceptor` and `WriterInterceptor`) are executed in ascending order of their priorities. In other words, the lesser-valued `@Priority` annotated providers are executed first.

The response filters (`ContainerResponseFilter` and `ClientResponseFilter`) are executed in exactly the opposite (that is, *descending*) order. In the absence of a `@Priority` annotation, a default value is assumed. It is defined by the `USER` constant in `javax.ws.rs.Priorities` (this equals 5,000). Priorities of client-side components can be set using the `register` method of interfaces implementing `Configurable`.

Support for Asynchronous Processing

JAX-RS 2.0 includes a brand-new API for asynchronous processing that includes server-side as well as client-side counterparts. Being asynchronous inherently implies request processing on a different thread than the thread that initiated the request. From a client perspective, asynchronous processing prevents blocking the request thread, because no time is spent waiting for a response from the server. Similarly, asynchronous processing on the server side involves the suspension of the original request thread and the initiation of request processing on a different thread, thereby freeing up the original server-side thread to accept other incoming requests. The end result of asynchronous processing (if it is leveraged correctly) is scalability, responsiveness, and greater throughput.

Server-side asynchronous processing. The server-side asynchronous programming model is mainly powered by the following API abstractions: the `@javax.ws.rs.container.Suspended` annotation and the `javax.ws.rs.container.AsyncResponse` interface.

An instance of `AsyncResponse` can be transparently injected as a method parameter (of a JAX-RS resource class) by annotating it with `@Suspended`. This instance serves as a callback object to interact with the caller/client and perform operations such as response delivery (postrequest processing completion), request cancellation, error propagation, and so forth.

```
@GET
@Path("/{id}")
public void search(
    @Suspended AsyncResponse asyncResp,
    @PathParam("id") String id){
    //launching search in a new thread
    new Thread(){
        public void run(){
            //execute search op and resume
```

```
        UserInfo user = //obtain via search...
        asyncResp.resume(user);
    }
}.start();
}
```

To propagate responses and exceptions, use the overloaded versions of the `resume` method on the `AsyncResponse` interface to return responses or exceptions back to the client.

To handle request processing timeouts, configure a timeout after which an HTTP 503 error response is returned to the client. This can be achieved by configuring a timeout threshold. By default, a timeout triggers an HTTP 503 error response. However, this can be overridden by registering a `javax.ws.rs.container.TimeoutHandler` implementation.

`javax.ws.rs.container.CompletionCallback` represents a callback interface whose implementation can be registered in order to execute business logic after the completion of the request. It is possible to terminate request processing by using overloaded versions of the `cancel` method. This results in an HTTP 503 error response being sent to the client.

Client-side asynchronous processing. The JAX-RS API allows asynchronous request invocations using the `Invocation` and the `AsyncInvoker` interfaces. The `Invocation` interface handles asynchronous submission via overloaded versions of the `submit` method, while the `AsyncInvoker` interface supports asynchronous invocation with dedicated methods (`get()`, `post()`, `put()`, and so on) for standard HTTP actions: GET, PUT, POST, DELETE, HEAD, TRACE, and OPTIONS.

Once registered, an implementation of the `Invocation Callback` will automatically be executed once the asynchronous request is processed. It provides the ability to account for scenarios that cause exceptions or that execute successfully. In the event that a `Future` object is obtained and no callback has been registered, manually poll it in order

to interact with the response. `isDone`, `get`, and `cancel` are some of the methods that can be invoked. The following illustrates response handling via a callback and a `Future` object:

```
Invocation.Builder builder1 = //...
AsyncInvoker invoker = builder1.async();

//obtain a Future
Future<Response> future1 = invoker.get();

//create another builder
Invocation.Builder builder2 = ...
Invocation invocation = builder2.buildGet();

//provide a callback
Future<Response> future2 =
    invocation.submit(
        new InvocationCallback<Customer>(){
            public void completed(Customer cust){
                System.out.println(
                    "Customer ID:" + cust.getID());
            }
            public void failed(Throwable t){
                System.out.println(
                    "Unable to fetch Cust details: " +
                    t.getMessage());
            }
        });
```

Enhanced Exception Handling

Before looking at the other new features in JAX-RS 2.0, let's review some of the existing exception-handling capabilities provided by the framework for robust exception handling. The `javax.ws.rs.core.Response` object allows you to wrap an HTTP error state and return it to the caller. A `javax.ws.rs.WebApplicationException` (unchecked exception) can be used as a bridge between the native busi-

ness- or domain-specific exceptions and an equivalent HTTP error response. A `javax.ws.rs.ext.ExceptionMapper` represents a contract (interface) for a provider that maps Java exceptions to `javax.ws.rs.core.Response` objects. It can be thought of as an enhanced version of a `javax.ws.rs.WebApplicationException` and helps embrace the “don’t repeat yourself” (DRY) principle for exception handling by allowing you to define flexible mappings between business-logic exceptions and the desired HTTP response, for example:

```
public class BookNotFoundExceptionMapper implements
    ExceptionMapper<BookNotFoundException>{
    @Override
    Response toResponse(
        BookNotFoundException bnfe){
        return Response.status(404).build();
    }
}
```

JAX-RS 2.0 has been supplemented with unchecked

EXCEPTION	HTTP ERROR CODE
BadRequestException	400
ForbiddenException	403
InternalServerErrorException	500
NotAcceptableException	406
NotAllowedException	405
NotAuthorizedException	401
NotFoundException	404
NotSupportedException	415
ServiceUnavailableException	503

Table 1. How exception classes map to HTTP error codes

exceptions that inherit from `javax.ws.rs.WebApplicationException`. This design relieves you from having to build and throw a `WebApplicationException` with explicit HTTP error information. The new exceptions are intuitively named, and each of them maps to a specific HTTP error scenario (by default). This means that throwing any of these exceptions from your resource classes will result in a predefined (as per mapping) HTTP error response being sent to the client; that is, the client would receive an HTTP 403 in the event that you throw a `NotAuthorizedException` (detailed mapping in **Table 1**). The exceptions' behavior can also be modified at runtime by using the `ExceptionHandler` to return a different `Response` object. **Figure 2** shows the new exception hierarchy.

A mapping of these exception classes to the corresponding HTTP error codes is shown in Table 1.

Other Notable Enhancements

Apart from the big-ticket features, several other useful enhancements were introduced as part of JAX-RS 2.0, which you should use if they fit your application.

@BeanParam. This annotation can be used to inject a custom POJO or bean whose instances can be annotated with various Param annotations such as @HeaderParam, @CookieParam, @PathParam, @QueryParam, and so on. As shown below, it provides a convenient way to capture HTTP URI parameters with the help of simple POJOs instead of injecting individual components from the HTTP request into JAX-RS resources:

```
public class CustomerSearchRequest{
    @QueryParam("id")
    private String userid;

    @HeaderParam("Accept")
    private String accept;

    @CookieParam("lastAccessed")
    private Date lastAccessed;
    //getters to fetch the values
}
```

The JAX-RS runtime injects an instance of the `@javax.ws.rs.BeanParam` annotated method argument (or an instance variable).

@ConstrainedTo. There are certain provider components in JAX-RS that are applicable to the server side and the client side. Interceptors are a good example where both `ReaderInterceptor` and `WriterInterceptor` can be applied on both the server side and the client side. The `@javax.ws.rs.ConstrainedTo` annotation can be applied on a provider class in order to (explicitly) restrict its contextual

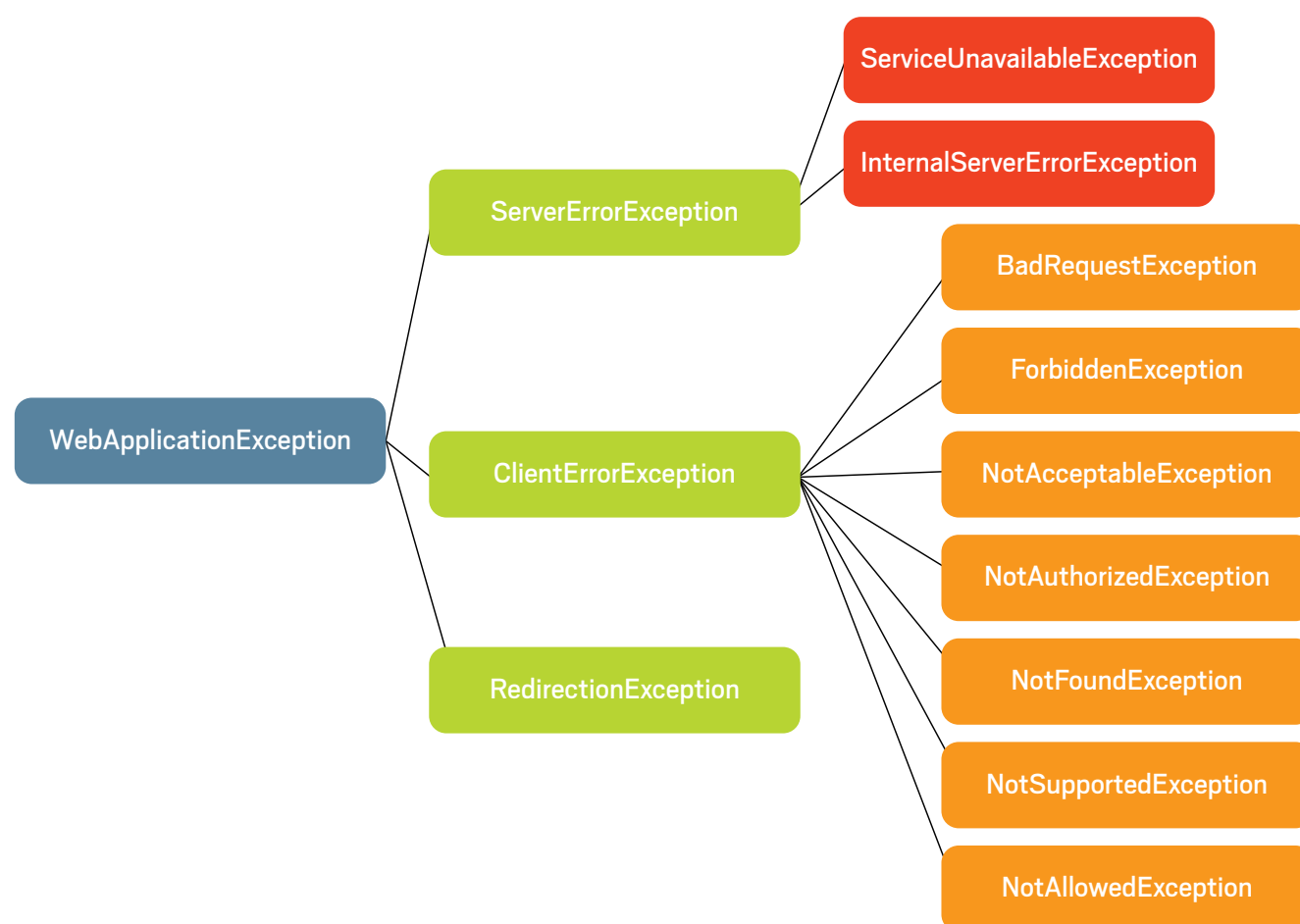


Figure 2. The hierarchy of JAX-RS 2.0 exceptions

ParamConverter. The `ParamConverter` interface comes in handy when handling custom objects or POJOs that do not satisfy the prerequisites for automatic injection (having a public constructor that takes a `String` argument or having a static `valueOf` method that takes a `String` argument and returns an instance of the same type as the POJO). An implementation of this interface can be used to provide custom logic for conversion of `String` parameters obtained via the `Param` annotations (`@QueryParam`, `@PathParam`, and so on) into custom POJOs.

The JAX-RS framework serves as a solid platform for building REST-oriented applications by providing a much needed abstraction on top of HTTP. The 2.0 release is a major overhaul with significant additions to the API. If you're not using the full range of options JAX-RS offers you, chances are good you're carrying around handwritten code that would benefit from being replaced by these capabilities. [</article>](#)

learn more

Roy Fielding's seminal paper on REST

JEP 254: Compact Strings

Interestingly, the information on the JEP's web page reveals that a string compression feature was tested in Java 6. It converted `String.value` to an `Object` that pointed either to an array of 7-bit characters or an array of regular Java characters. That feature, though, was removed subsequently.

Long Polling with Asynchronous Servlets

HENRY NAFTULIN

The reliable workhorse of client/server communications is the easy-to-use fallback when other methods don't work.

Not too long ago, a large gap existed between desktop applications and web applications. If you go back 10 years, desktop applications were noticeably more responsive, had far better user interfaces, and overall presented a much better user experience. A major reason why web-based applications were far behind in user experience was because they were not as responsive to server state changes as their desktop counterparts, and users had to update a whole page to get new data on the screen. Back then, in order to compete with desktop apps, companies that produced web applications used a variety of different tactics. They used applets, Adobe Flash applications, Comet, or similar frameworks that were popular at the time, while others used raw Ajax calls. Even with all these technologies, web apps couldn't compete with desktop software for usability.

Nowadays, web applications are expected to be interactive, have a stellar-looking UI, and do almost as much as their desktop counterparts. With rich front-end UI frameworks such as Bootstrap and processing frameworks such as jQuery and Angular JS, it is much easier to build applications that are easy on the eyes and can quickly respond to user input notifying a server about changes made in the UI.

But what about propagating the changes from the server to the web clients? After all, given today's cutting-edge technology, we are used to and expect almost instant-

neous UI feedback to anything that is happening to the information on the server. In this article I explore one such solution—long polling—and briefly take a look at its alternatives.

Long Polling and Its Alternatives

For a long time, web applications were developed in an n -tiered (usually three-tiered) architecture, in which the client initiated requests for data from the server. There was no way for the server to push data to the client without the client requesting an update. Yet in many applications, a change on the server needs to be propagated to the clients in a timely manner. To work around this limitation, a technique known as *long polling* can be used.

Long polling is a technique used to push updates to a web client. After a client requests new information, the server holds the request until new data becomes available. Once the server receives new data, it completes the client's response by sending the data to the client. At this point the server can either keep the connection open while sending further updates to the client as they happen, or close the connection right away. In the latter case, once the client receives the response from the server and the connection is closed, the client immediately sends another request for an update and the operation is repeated.



As such, long polling remains a significant player and a reliable solution. It is useful to know how it works and how to implement it efficiently.

Yet, with long polling, the difference in scalability between thread per connection and thread per request is blurred. This is because each request must wait for data to be available on the server before generating the response. Waiting in the servlet is inefficient, because the server thread that could be used to service another request is blocked. Prior to Servlet 3.0, this resulted in poor scalability as users were added to the application.

Servlet 3.0 introduced *asynchronous processing*, which is a way for servers to process requests, particularly those in which a long-running operation such as a remote call or an application event must happen before a response can be generated. Prior to the Servlet 3.0 specification, a servlet would block a response thread and hold on to other limited resources while it waited for a response to be generated. With asynchronous

processing enabled, we can use a different thread to process the request and dispatch a response to the user. This change frees the original servlet request thread right away, so that it is returned to the servlet container to service other requests from other users.

Servlet 3.0 makes coding asynchronous processing simple by introducing `AsyncContext`—an execution context for asynchronous operations. `AsyncContext` encapsulates servlet request and response and lets you work with them outside of the original servlet processing thread. To use `AsyncContext`, you first need to indicate your intent to the servlet container—for example, by adding `asyncSupported=true` to your servlet annotation. Then, to put a request into asynchronous mode, you need to create an instance of `AsyncContext` inside the servlet's service call method. This can be done with

```
AsyncContext asyncContext =
    request.startAsync(request, response);
```

At this point, the asynchronous request processing can be delegated to a different thread or put in a queue for processing later. Because servlet request and response objects are encapsulated with `AsyncContext`, they are available to any thread and are not tied to the original servlet thread. This allows the original servlet thread to finish the service call without waiting for the asynchronous response to be completed and to be available to service requests from other clients.

A Simple Example of Asynchronous Long Polling

Let's look at the simple example of a web chat application that demonstrates the advantages of asynchronous servlet processing. In this application, the user types a username and a message and then clicks Send (see **Figure 1**). This message will then appear on all the browsers polling the chat URL.

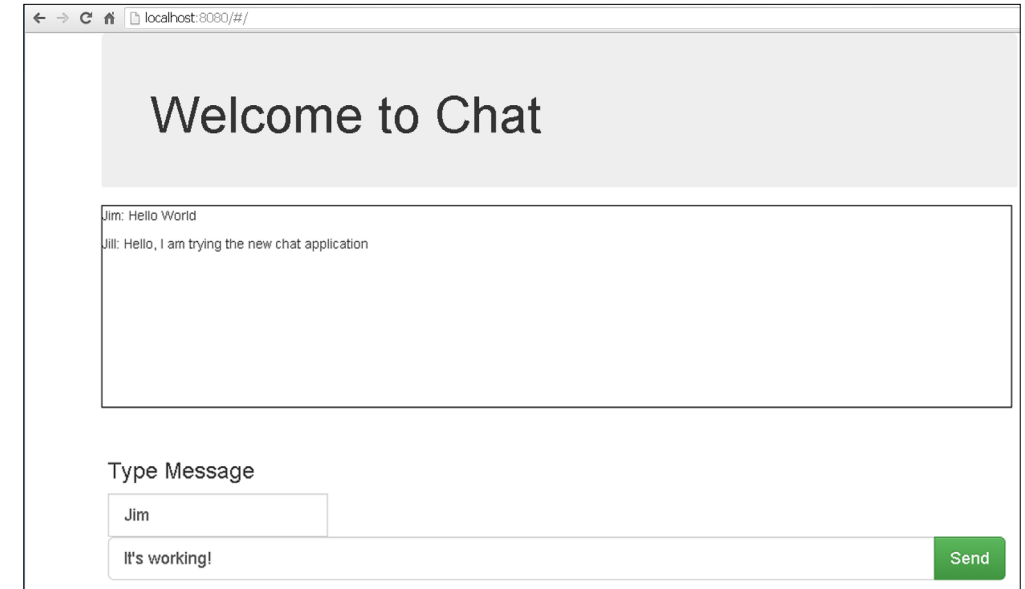


Figure 1. Chat app that broadcasts incoming messages

The code in **Listing 1** shows the key communication portions of the chat app.

■ Listing 1.

```
@WebServlet(urlPatterns="/chatApi",
            asyncSupported=true,
            loadOnStartup = 1)
public class AsyncChatServletApi
    extends HttpServlet {

    ...

    private static final int
        NUM_WORKER_THREADS = 10;
    Lock lock = new ReentrantLock();
    LinkedList<AsyncContext> asyncContexts =
        new LinkedList<>();

    private AsyncListener listener =
        new ChatAsyncListener();

    @Override
    public void doGet(HttpServletRequest request,
                     HttpServletResponse response)
        throws IOException {
        AsyncContext asyncContext =
```

```

        request.startAsync(request, response);

        asyncContext.setTimeout(-1);
        asyncContext.addListener(listener);
        try {
            lock.lock();
            asyncContexts.addFirst(asyncContext);
        } finally {
            lock.unlock();
        }
    }

    @Override
    public void doPost(HttpServletRequest request,
                       HttpServletResponse response)
        throws IOException {

        final String message = getMessage(request);
        Collection<AsyncContext> localCopy;
        try {
            lock.lock();
            localCopy= asyncContexts;
            asyncContexts = new LinkedList<>();
        } finally {
            lock.unlock();
        }

        for(AsyncContext asyncContext : localCopy) {
            Runnable runnable =
                new RunnableWriter(asyncContext, message);
            executor.execute(runnable);
        }
        localCopy.clear();
    }

    private String getMessage(...) { ... }

    class RunnableWriter implements Runnable {
        private final AsyncContext asyncContext;
        private final String message;
    }
}

```

```
public RunnableWriter(..) { .. }

@Override
public void run() {
    try(PrintWriter writer =
        asyncContext.getResponse().getWriter()) {
        writer.println(message);
        writer.flush();
        asyncContext.complete();
    } catch(Exception e) {
        ...
    }
}
}
```

This code example implements an asynchronous servlet that is tied to the `/chatApi` path. A collection is created in which the multiple asynchronous contexts are stored. It contains servlet contexts that are waiting to receive a chat message once it is available. So instead of tying up servlet processing threads to wait until someone sends a chat message, the `AsyncContext` is created and stored right away to be processed at a later time, when a new chat message becomes available.

Two REST APIs are used: `doGet` and `doPost`, which are shown here as the first two methods in the `AsyncChatServletApi` class. `doGet` subscribes a user to receive a new chat message, while `doPost` pushes a new chat message to all waiting clients. Specifically, when the user hits a get URL, an asynchronous context is created by calling

```
AsyncContext asyncContext =
    request.startAsync(request, response);
```

Following that, the asynchronous context is saved in a list of contexts. This is a list representing clients that are waiting to get the next chat message. At this point, the server thread

is done with processing this request, and it can be reused for processing other requests.

When a user issues a `doPost` request posting a chat message, the message is retrieved. This message is then written to each of the asynchronous contexts, and the processing is completed by calling

```
asyncContext.complete();
```

Because the servlet can be called by multiple threads, the processing thread must be made thread-safe. In particular, three scenarios should be addressed:

- Two post requests are processed simultaneously.
- A get request is received while a post request is being processed.
- Two get requests are processed simultaneously.

When two posts occur simultaneously or a get and a post occur simultaneously, all clients waiting for a message should receive it (that is, messages are not dropped). This can be achieved by synchronizing the copying context into a local collection, and reinitializing the member context collection so that it can accumulate new requests. Choosing to synchronize the addition of an element to a collection in the `doGet` method and synchronizing creation of a local copy of a request collection in `doPost` takes care of both scenarios.

In the case of two get requests being processed simultaneously, both contexts need to be stored for future processing. This can be achieved by having a thread-safe collection. Alternatively, it is possible to synchronize the block of code that adds an element, as shown in **Listing 1**.

Now, let's examine the timeouts. If we were to set a non-infinite timeout on the asynchronous context, and the timeout is reached, clients receive the response "Server returned HTTP response code: 500 for URL: http://localhost:8080/chat-api." If the timeout is not set explicitly, the request inherits the default timeout from the server settings. If the timeout

is set as 0 or negative, as shown in **Listing 1**, the server never times out the request (although a web client can). To handle timeouts on the server, you can extend `AsyncListener` and implement custom code in the `onTimeout` callback event. For instance, changing the server response to send status code 408 (the HTTP code for request timeout) along with the message “Request timeout, no chat messages so far, please try again” can be achieved by using the code in **Listing 2**.

■ Listing 2.

```
public class ChatAsyncListener
    implements AsyncListener {

    @Override
    public void onComplete(AsyncEvent event) { }

    @Override
    public void onTimeout(AsyncEvent event) {
        AsyncContext asyncContext
            = event.getAsyncContext();
        HttpServletResponse response
            = (HttpServletResponse)
                asyncContext.getResponse();
        response.sendError(
            HttpServletResponse.SC_REQUEST_TIMEOUT,
            "Request timeout, no chat messages so far,"
            + " please try again.");

        asyncContext.complete();
    }

    @Override
    public void onError(AsyncEvent event) { }

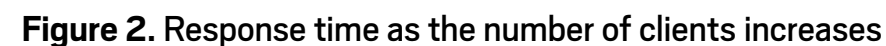
    @Override
    public void onStartAsync(AsyncEvent event) { }

}
```



Another interesting point this test demonstrates is that the average time it takes to consume a message is slightly below the rate at which messages are produced. It indicates that

Table 1. Results of three runs sending messages to multiple clients (time in ms)



To enhance this setup to work in an environment where missing messages is not a viable option, a client can pass a token to the server indicating the last message it has seen. If the client has already received the latest message available, the server puts the thread on asynchronous wait for a new message. Otherwise, the server responds with all messages produced since the last message the client received.

In this article, I've explained what long polling is and demonstrated how simple it is to use. With the universal support it enjoys, long polling can be used anytime a long-lived connection between client and server is needed. </article>

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In [Part 1](#) of this article, I introduced WebSockets. I observed that the base WebSocket protocol gives us two native formats to work with: text and binary. This works well for very basic applications that exchange only simple information between client and server. For example, in the Clock application in that article, the only data that is exchanged during the WebSocket messaging interaction is the formatted time string broadcast from the server endpoint and the `stop` string sent by the client to end the updates. But as soon as an application has anything more complicated to send or receive over a WebSocket connection, it will find itself seeking a structure into which to put the information. As Java developers, we are used to dealing with application data in the form of objects: either from classes from the standard Java APIs or from Java classes that we create ourselves. This means that if you stick with the lowest-level messaging facilities of the Java WebSocket API and want to program using objects that are not strings or byte arrays for your messages, you need to write code that converts your objects into either strings or byte arrays and vice versa. Let's see how that's done.

First, the Java WebSocket API attempts to convert incoming messages into any Java primitive type (or its class equiv-

This only gets you so far. Often, you want higher-level, highly structured objects to represent the messages in your application. In order to handle custom objects in your message handling methods, you must provide, along with the

endpoint, a WebSocket **Decoder** implementation, which the runtime uses to convert the incoming message into an instance of the custom object type. To handle custom objects in your send methods, you must provide a WebSocket **Encoder** implementation that the runtime will use to convert instances of the custom object into a native WebSocket message. We can summarize this kind of scheme in **Figure 1**.

Figure 1 shows endpoints exchanging strings with the client at the top, and other endpoints using an encoder and a decoder for converting `Foo` objects into WebSocket text messages and vice versa.

There is a family of `javax.websocket.Decoder` and `javax.websocket.Encoder` interfaces in the Java WebSocket API to choose from, depending on what kind of conversion you wish to make. For example, to implement a `Decoder` that converts text messages into instances of a custom developer class called `Foo`, you would implement the interface `Decoder.Text<T>` using `Foo` as the generic type, which would require you to implement this method:

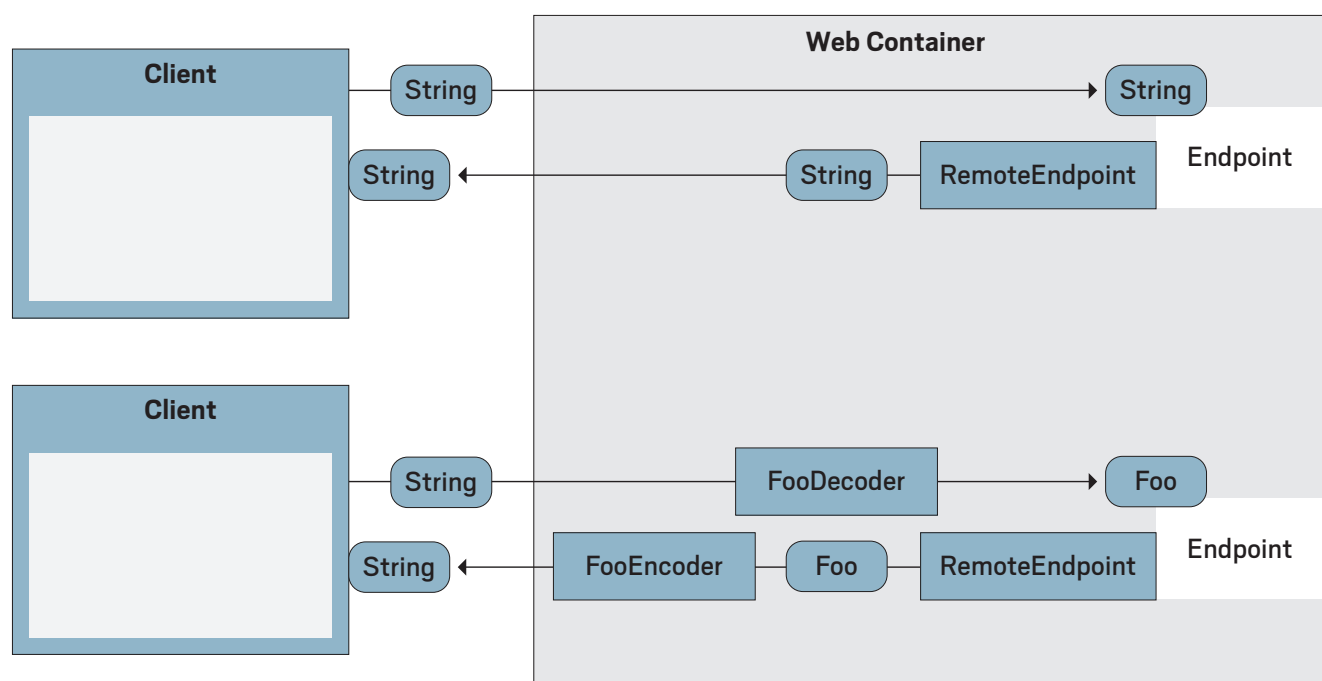


Figure 1. Encoders and decoders

```
public void sendObject(Object message)
    throws IOException, EncodeException
```

This is the workhorse method of the decoder and would be called each time a new text message came in to produce an instance of the `Foo` class. The runtime would then be able to pass this class into the message handling method of your endpoint.

There are sibling **Decoder** classes for decoding binary WebSocket messages and WebSocket messages that arrive in the form of a blocking I/O stream (which is also supported).

To implement an `Encoder` that converts instances of a custom developer class `Foo` into a WebSocket text message, you would implement the `Encoder.Text<T>` interface using `Foo` as the generic type. This would require you to implement this method:

```
public String encode(Foo foo)
    throws EncodeException
```

This does the work of converting `Foo` instances into strings, which are needed by the Java WebSocket runtime if you call the `RemoteEndpoint`'s `sendObject()` method (discussed previously), passing in an instance of the class `Foo`. Like `Decoders`, there are `Encoder` siblings for converting custom objects into binary messages and for writing custom objects to blocking I/O streams in order to send the message.

This scheme is easy to wire into an endpoint if you want to use it, as we saw in the definitions for `@ClientEndpoint` and `@ServerEndpoint`. You can simply list the decoder and encoder implementations you want the endpoint to use in the `decoders()` and `encoders()` attributes, respectively.

If you configure your own encoders or decoders for the Java primitive types, they will override the runtime's default encoders or decoders for those types, just as you would expect.

Message Processing Modes

So far, we have only discussed sending and receiving WebSocket messages one entire message at a time. Although many applications retain this simple model for message processing because they define only small messages in their application protocol, some applications will deal with large WebSocket messages, perhaps transmitting photographs or large documents. The Java WebSocket API provides several processing modes suited to handling larger messages gracefully and efficiently.

Receiving large messages. The Java WebSocket API has two additional modes for receiving messages that are suited to situations when you know the message will be large. The first mode exposes the endpoint to a blocking I/O API that the endpoint can use to consume the message, either `java.io.Reader` for text messages or `java.io.InputStream` for binary messages. To use this mode, instead of using either a `String` or `ByteBuffer` parameter in your message handling method, you would use a `Reader` or `InputStream`. For example,

```
@OnMessage
public void handleMessageAsStream(
    InputStream messageStream,
    Session session) {
    // read from the messageStream
    // until you have consumed the
    // whole binary message
}
```

The second mode allows for a kind of elementary chinking API, where the WebSocket message is passed to the message handler method in small pieces together with a `boolean` flag telling you whether there are more pieces yet to come in order to complete the message. Of course, the message pieces arrive in order, and there is no interleaving of other messages. To

use this mode, the message handler method adds a `boolean` parameter. For example,

```
@OnMessage
public void handleMessageInChunks(
    String chunk, boolean isLast) {
    // reconstitute the message
    // from the chunks as they arrive
}
```

In this mode, the size of the chunks depends on several factors relating to the peer that sends the message and the configuration of the Java WebSocket runtime. All you know is that you will receive the whole message in a number of pieces.

Modes for sending messages. As you might expect, given the symmetry of the WebSocket protocol, there are equivalent modes for sending messages in the Java WebSocket API suited to large message sizes. In addition to sending a message all in one piece, as we have seen so far, you can send messages to a blocking I/O stream, either `java.io.Writer` or `java.io.OutputStream` depending on whether the message is text or binary. These are, of course, additional methods on the `RemoteEndpoint.Basic` interface that you obtain from the `Session` object:

```
public Writer getSendWriter() throws IOException
```

and

```
public OutputStream getSendStream()
    throws IOException
```

The second mode is the chunking mode, but in reverse, for sending rather than receiving. Again, an endpoint can send messages in this mode by calling either of the following methods of `RemoteEndpoint.Basic`,

In general, an endpoint is accessible at

```
<ws or wss>://<hostname>:<port>/  
<web-app-context-path>/<websocket-path>?  
<query-string>
```

where `<websocket-path>` is the `value` attribute of the `@ServerEndpoint` annotation and `query-string` is an optional query string.

When the `<websocket-path>` is a URI, as it is in the `ClockServer` endpoint, the only request URI that will connect to the endpoint is the one that matches it exactly.

The Java WebSocket API also allows server endpoints to be mapped to level 1 URI templates. URI templates are a fancy way of saying that one or more segments of the URI can be substituted with variables. For example,

```
/airlines/{service-class}
```

is a URI template with a single variable called `service-class`.

The Java WebSocket API allows incoming request URIs to match an endpoint using a URI template path mapping if and only if the request URI is a valid expansion of the URI template. For example,

```
/airlines/coach
/airlines/first
/airlines/business
```

are all valid expansions of the URI template

```
/airlines/{service-class}
```

with variable `service-class` equal to `coach`, `first`, and `business`, respectively.

URI templates can be very useful in a WebSocket application, because the template variable values are available

within the endpoint that matches the request URI. In any of the lifecycle methods of a server endpoint, you can add as many String parameters annotated with the `@PathParam` annotation to obtain the value of the variable path segments in the match. Continuing this example, suppose we had the server endpoint shown in Listing 1.

■ Listing 1. A Booking notifier endpoint

```
@ServerEndpoint("/airlines/{service-class}")
public class MyBookingNotifier {

    @OnOpen
    public void initializeUpdates(Session session,
        @PathParam("service-class") String sClass) {
        if {"first".equals(sClass)) {
            // open champagne
        } else if ("business".equals(sClass)) {
            // heated nuts
        } else {
            // don't bang your head on our aircraft
        }
    }
}

...
}
```

This would yield different levels of service, depending on which request URI a client connects with.

Accessing path information at runtime. An endpoint has full access to all of its path information at runtime. First, it can always obtain the path under which the WebSocket implementation has published it. Using the `ServerEndpointConfig.getPath()` call for the endpoint holds this information, which you can easily access wherever you can get hold of the `ServerEndpointConfig` instance, such as we see in Listing 2.

■ **Listing 2.** An endpoint accessing its own path mapping

```
@ServerEndpoint("/travel/hotels/{stars}")
public class HotelBookingService {
    public void handleConnection{
        Session s, EndpointConfig config) {
            String myPath =
                ((ServerEndpointConfig) config).getPath();
            // myPath is "/travel/hotels/{stars}"
            ...
        }
    }
}
```

This approach will work equally well for exact URI-mapped endpoints.

The second piece of information you may wish to access at runtime from within an endpoint is the URI with which the client to your endpoint connected. This information is available in a variety of forms, as we shall see later, but the work-horse method that contains all the information is the

```
Session.getRequestURI()
```

method. This gives you the URI path relative to the web server root of the WebSocket implementation. Notice that this includes the context root of the web application that the WebSocket is part of. So, in our hotel booking example, if it is deployed in a web application with context root `/customer/services` and a client has connected to the `HotelBookingService` endpoint with the URI

```
ws://fun.org/customer/services/
travel/hotels/3
```

then the request URI the endpoint receives by calling `getRequestURI()` is

/customer/services/travel/hotels/3

Two more methods on the `Session` object parse out further information from this request URI when the request URI includes a query string. So let's take a look at query strings.

Query strings and request parameters. As we saw earlier, following the URI path to a WebSocket endpoint is the optional query string

```
<ws or wss>://<host:name>:<port>/  
    <web-app-context-path>/<websocket-path>?  
    <query-string>
```

Query strings in URIs originally became popular in common gateway interface (CGI) applications. The path portion of a URI locates the CGI program (often `/cgi-bin`), and the query string appended after the URI path supplies a list of parameters to the CGI program to qualify the request. The query string is also commonly used when posting data using an HTML form. For example, in a web application, in the HTML code

```
<form
  name="input"
  action="form-processor" method="get">
  Your Username: <input type="text" name="user">
                <input type="submit"
value="Submit">
</form>
```

clicking the Submit button produces an HTTP request to the URI

```
/form-processor?user=Jared
```

relative to the page holding the HTML code and where the input field contains the text **Jared**. Depending on the nature of the web resource located at the URI path **/form-processor**, the query string **user=Jared** can be used to determine what kind of response should be made.

For example, if the resource at `form-processor` is a Java servlet, the Java servlet can retrieve the query string from the `HttpServletRequest` using the `getQueryString()` API call.

In a similar spirit, query strings can be used in the URIs that are employed to connect to WebSocket endpoints created with the Java WebSocket API. The Java WebSocket API does not use a query string sent as part of the request URI of an opening handshake request to determine the endpoint to which it might match. In other words, whether or not a request URI contains a query string makes no difference to whether it matches a server endpoint's published path. Additionally, query strings are ignored in paths used to publish endpoints.

Just as CGI programs did and other kinds of web components do, WebSocket endpoints can use the query string to further configure a connection that a client is making. Because the WebSocket implementation essentially ignores the value of the query string on an incoming request, any logic that uses the value of the query string is purely inside the WebSocket component. The main methods that you can use to retrieve the value of the query string are all on the `Session` object

```
public String getQueryString()
```

which returns the whole query string (everything after the `?` character) and

```
public Map<String,List<String>>
    getRequestParameterMap()
```

which gives you a data structure with all the request parameters parsed from the query string. You'll notice that the values of the map are lists of strings; this is because a query string may have two parameters of the same name but different values. For example, you might connect to the `HotelBookingService` endpoint using the URI

```
ws://fun.org/customer/
    services/travel/hotels/4?
    showpics=thumbnails&
    description=short
```

In this case, the query string is `showpics=thumbnails&description=short`, and to obtain the request parameters from the endpoint, you might do something like what's shown in Listing 3.

■ Listing 3. Accessing request parameters

```
@ServerEndpoint("/travel/hotels/{stars}")
public class HotelBookingService2 {

    public void handleConnection(
        Session session, EndpointConfig config) {
        String pictureType =
            session.getRequestParameterMap()
                .get("showpics").get(0);
        String textMode =
            session.getRequestParameterMap()
                .get("description").get(0);
        ...
    }
    ...
}
```

where the values of `pictureType` and `textMode` would be `thumbnails` and `short`, respectively.

You can also get the query string from the request URI. In the Java WebSocket API, the `Session.getRequestURI` call always includes both the URI path and the query string.

Deployment of Server Endpoints

Deployment of Java WebSocket endpoints on the Java EE web container follows the rule that easy things are easy. When you package a Java class that has been annotated with `@ServerEndpoint` into a WAR file, the Java WebSocket



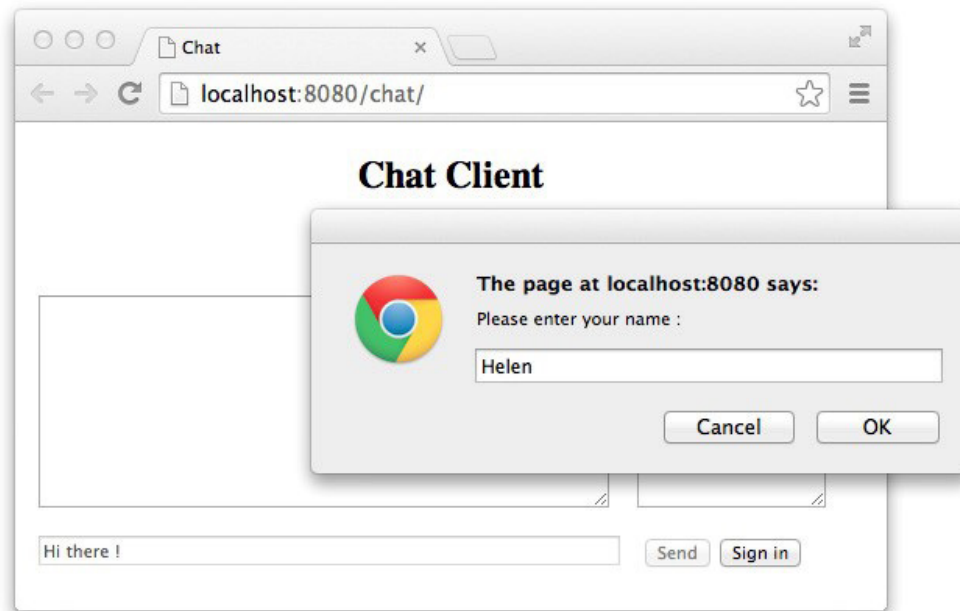


Figure 2. Logging in to chat

implementation scans the WAR file and finds all such classes and deploys them. This means there is nothing special you have to do in order to get your server endpoints deployed except package them in the WAR file. However, you may wish to more tightly control which of a collection of server endpoints gets deployed in a WAR file. In this case, you may provide an implementation of the Java WebSocket API interface `javax.websocket.ServerApplicationConfig`, which allows you to filter which of the endpoints get deployed.

The Chat Application

A good way to test a push technology is to build an application that has frequent, asynchronous updates to make to a number of interested clients. Such is the case with a Chat application. Let's take a look in some detail at how to apply what we have learned about the Java WebSocket API to build a simple chat application.

Figure 2 shows the main window of the Chat application, which prompts for a username when you sign in.

Several people can be chatting all at once, typing their messages in the text field at the bottom and clicking the Send

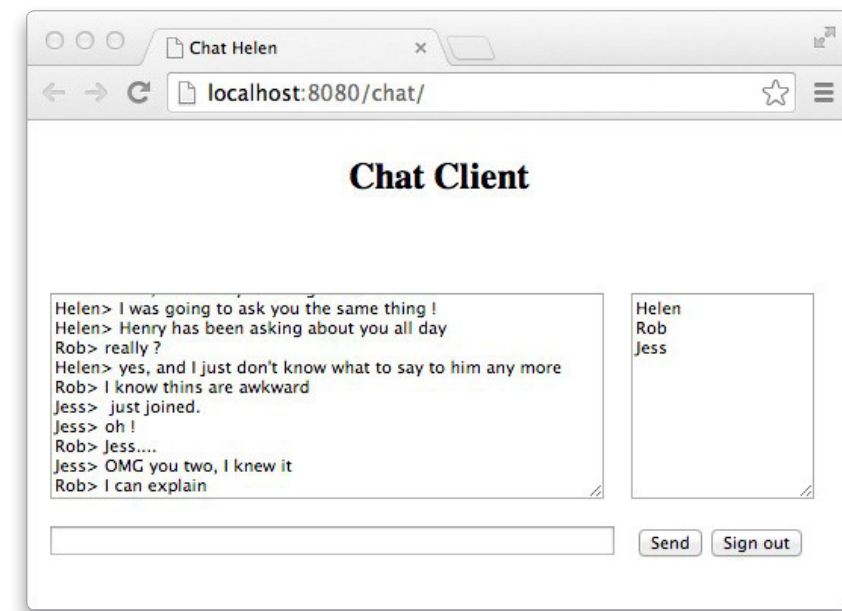


Figure 3. Chat in full flow

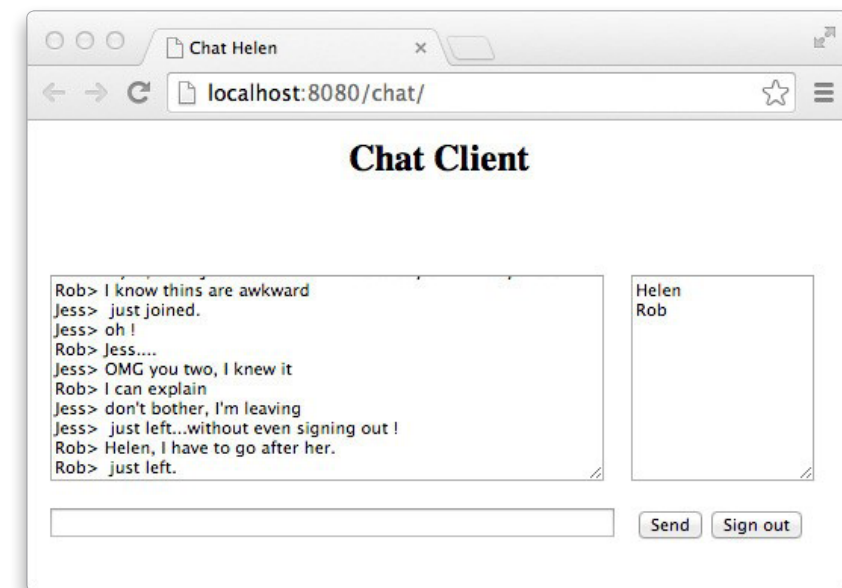


Figure 4. Leaving chat

button. You can see the active chatters on the right side and the shared transcript recording everyone's messages in the middle and left. In Figure 3, there is an uncomfortable triad of people chatting.

In Figure 4, we can see that one of the chatters left rather suddenly, and the other has left slightly more gracefully, leaving just one chatter in the room.



Before we look at the code in detail, let's get the big picture of how this application is built. The web page uses the JavaScript WebSocket client to send and receive all the chat messages. There is a single **ChatServer** Java WebSocket endpoint on the web server, which is handling all chat messages from multiple clients, keeping track of those clients that are actively chatting, maintaining the transcript, and broadcasting updates to all connected clients whenever someone enters or leaves the chat room and whenever any one of them sends a message to the group. The application uses custom objects with WebSocket **Encoders** and **Decoders** to model all the chat messages.

Let's look at the `ChatServer` endpoint in Listing 4. [Due to its length, the listing should be downloaded from this issue's download area. —*Ed.*]

There is a lot to notice in this code. First, notice that this is a server endpoint that is mapped to the relative URI `/chat-server`. The endpoint uses an encoder and a decoder class, `ChatEncoder` and `ChatDecoder`, respectively.

The best way to look at Java WebSocket endpoints for the first time is to look at the lifecycle methods: These, as you know, are the methods annotated by `@OnOpen`, `@OnMessage`, `@OnError`, and `@OnClose`. We can see by looking at the `ChatServer` class in this way that the first thing the `ChatServer` WebSocket does when a new client connects is to set up instance variables that reference the chat transcript, the session, and the `EndpointConfig`. Remember that there is a new instance of the endpoint for each client that connects. So each chatter in the chat room will have a unique chat server instance associated with it. There is always a single `EndpointConfig` per logical WebSocket endpoint, so the `endpointConfig` instance variable on each instance of the `ChatServer` points to the single shared instance of the `EndpointConfig` class. This instance is a singleton, and it holds a user map that can hold an arbitrary application state. Thus, it is a good place to hold global state in an application.

There is always a unique session object per client connection, so each `ChatServer` instance points to its own `Session` instance representing the client to which the instance is associated by following the code to the `Transcript` class, as shown in **Listing 5**.

■ Listing 5. The Transcript class

```
import java.util.ArrayList;
import java.util.List;
import javax.websocket.*;

public class Transcript {
    private List<String> messages =
        new ArrayList<>();
    private List<String> usernames =
        new ArrayList<>();
    private int maxLines;
    private static String
        TRANSCRIPT_ATTRIBUTE_NAME =
            "CHAT_TRANSCRIPT_AN";

    public static Transcript
        getTranscript(EndpointConfig ec) {
        if (!ec.getUserProperties().
            containsKey(TRANSCRIPT_ATTRIBUTE_NAME)) {
            ec.getUserProperties().
                .put(TRANSCRIPT_ATTRIBUTE_NAME,
                    new Transcript(20));
            return (Transcript) c.getUserProperties().
                .get(TRANSCRIPT_ATTRIBUTE_NAME);
        }

        Transcript(int maxLines) {
            this.maxLines = maxLines;
        }

        public String getLastUsername() {
            return usernames.get(usernames.size() - 1);
        }
    }
}
```

The most important method on the `ChatServer` is the message handling method, annotated with `@OnMessage`. You can see from its signature that it deals with `ChatMessage` objects rather than text or binary WebSocket messages, thanks to the `ChatDecoder` that it uses. The `ChatDecoder` it uses has already decoded the message into one of the subclasses of `ChatMessage`. In the interest of brevity, rather than listing all the `ChatMessage` subclasses, **Table 1** is a sum-

Table 1. The ChatMessage subclasses

Let's follow the code path when a `ChatServer` is notified that the user has posted a new chat message. This leads us from the `handleChatMessage()` method to the `processChatUpdate()` method, which calls `addMessage()`, adding the new chat message to the shared transcript. Then it calls `broadcastTranscriptUpdate()`, as shown in Listing 6.

```
private void broadcastTranscriptUpdate() {
    for (Session nextsession :
        session.getOpenSessions()) {
        ChatUpdateMessage cdm =
            new ChatUpdateMessage(
                this.transcript.getLastUsername(),
                this.transcript.getLastMessage());

        try{
            nextsession.getBasicRemote().sendObject(cdm);
        } catch (IOException | EncodeException ex) {
            System.out.println(
                "Error updating a client : " +
                ex.getMessage());
        }
    }
}
```

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connections to broadcast the new chat message out to all the clients so that they can update their user interfaces with the latest chat message. Notice that the message that is sent is in the form of a `ChatMessage`—here, the `ChatUpdateMessage`. The `ChatEncoder` takes care of marshaling the `ChatUpdateMessage` instance into a text message that is sent back to the client with the news contained within.

Because we did not look at the `ChatDecoder` when we were looking at incoming messages, let's pause to look at the `ChatEncoder` class, as shown in Listing 7.

■ Listing 7. The ChatEncoder class

```
import java.util.Iterator;
import javax.websocket.EncodeException;
import javax.websocket.Encoder;
import javax.websocket.EndpointConfig;

public class ChatEncoder implements
    Encoder.Text<ChatMessage> {
    public static final String SEPARATOR = ":";

    @Override
    public void init(EndpointConfig config) {}

    @Override
    public void destroy() {}

    @Override
    public String encode(ChatMessage cm)
        throws EncodeException {
        if (cm instanceof StructuredMessage) {
            String dataString = "";
```

The `encode()` method is **the meat of the class** and turns the message instance into a string, ready for transmission back to the client.

```

        for (Iterator itr =
            ((StructuredMessage) cm)
                .getList().iterator();
            itr.hasNext(); )
        {
            dataString =
                dataString + SEPARATDR +
                itr.next();
        }
        return cm.getType() + dataString;
    } else if (cm instanceof BasicMessage) {
        return cm.getType() +
            ((BasicMessage) cm).getData();
    } else {
        throw new EncodeException(cm,
            "Cannot encode messages of type: " +
            cm.getClass());
    }
}
}

```

You can see that the `ChatEncoder` class is required to implement the `Encoder` lifecycle methods `init()` and `destroy()`. Although this encoder does nothing with these callbacks from the container, other encoders may choose to initialize and destroy expensive resources in these lifecycle methods. The `encode()` method is the meat of the class and takes the message instance and turns it into a string, ready for transmission back to the client.

Returning now to the `ChatServer` class, we see from the `handleChatMessage()` method that this endpoint has a graceful way of dealing with clients that sign off in the proper way: by sending a `UserSignoffMessage` prior to closing the connection. It also has a graceful way of dealing with clients who simply close the connection unilaterally, perhaps by closing the browser or navigating away from the page. The `@OnClose` annotated `endChatChannel()` method broadcasts a message to all connected clients informing them

BEN EVANS

An Early Look at Java 9 Modules

Preparing for modularity, a significant change that is the cornerstone of the next major release of Java

Until now—that is, up through Java 8—the language’s model for controlling access to code has been relatively straightforward:

- Classes are arranged into packages. Packages are globally visible and open for extension (with the exception of packages that start with *java* or *javax*). Packages are designed for the logical organization of code and nothing more.
- The unit of delivery for code is the JAR file. Regular (unprotected) packages can span multiple JAR files.
- Classes and methods can restrict access. For example, they can enforce that they are accessible only to instances of the same type or to other code in the same package. This is expressed by the familiar Java keywords for access control.

This design has the advantage of being simple to understand and to reason about. However, it does lead to several issues related to access control. Of these, the most important problem is this: non-JDK libraries are powerless to prevent client code from creating additional classes in the libraries' packages. Creating such classes gives access to all of the protected and package-access classes (and methods) that are defined in the package.

This is sometimes referred to as the “shotgun privacy” problem, after this famous observation about the Perl programming language by its designer, Larry Wall: “Perl doesn’t have an infatuation with enforced privacy. It would prefer that you stayed out of its living room because you weren’t invited, not because it has a shotgun.”

For Java, however, shotgun privacy represents an important issue. As the language and environment currently stand, there's

no way to control access across an entire package. Another way of saying this is that Java libraries want to be able to define a public API and know with certainty that clients of that API can't subvert it or directly couple to the package internals.

Many enterprise applications would very much like to enforce a tight level of access control, where the only accesses are through a known and enforced API. However, this level of control of APIs is not completely possible in Java 8 and below. This was one of the principal reasons that Oracle (and previously Sun) wanted to develop a set of technologies capable of implementing this level of safety. As became clear, though, work on this problem began to allow the possibility of solving other problems.

The resulting core goals of the upcoming JDK 9 modules system have become the following over time:

- Extend access control so public APIs can be fully enforced by introducing a concept of “sealing” access within a deployment unit.
- Facilitate modular deployment of code at a scale larger than a single package.
- Modularize the JDK itself so that the platform can improve JVM startup times, reduce resource consumption, remove packages that shouldn’t be in the core, and remove or hide internal classes to reduce the attack surface of the platform.

Oracle has sponsored a project within OpenJDK, called Project Jigsaw, whose mission is to deliver modularity for the Java environment. As the release date for JDK 9 starts to approach, code from Jigsaw has begun to be migrated into the mainline OpenJDK repositories. This means that at the

time of this writing (late 2015), there are different binaries at various levels of completeness that support modules.

- The first Java 9 early access (EA) builds from Oracle that contain modules are available. However, the module functionality that is contained in these binaries is limited.
- To supplement the mainline JDK 9 builds and provide even earlier access to modular functionality, the Jigsaw project is also making binaries available.

For the rest of this article, the examples and discussion center on the Jigsaw binaries, because they are more complete than the JDK 9 mainline.

The Jigsaw Pieces

Project Jigsaw identified several subgoals in the course of a roadmap leading to full modularity. These were defined within the Java Enhancement Process (JEP) and included the following:

- Modularize the layout of the source code in the JDK (JEP 201).
- Modularize the structure of the binary runtime images (JEP 220).
- Disentangle the complex implementation dependencies between JDK packages.

This last goal was one of the most labor-intensive, but it was also necessary in order to make modules as independent from each other as possible. In turn, this goal allows the maximum possible flexibility for modules to be loaded and linked separately.

As an example of why this is needed, consider the `java.util.Properties` package, which contains a requirement to parse XML. This requirement greatly increased the footprint for any code that depended on `Properties`, because it pulled in Java’s full XML libraries. To fix this, a small XML parser based on the original reference implementation (JSR 280) was added to remove the heavier dependencies.

Another example is the RMI-IIOP transport, which was separated out from the management module, so that the

remote management module (which uses JMX) no longer requires CORBA to be present.

One other minor change is also worth mentioning because it is rather unusual in Java's history. A small number of methods in `java.util.logging.LogManager` were removed from the public API, because they caused undesirable linkages between some modules and would have introduced considerable bloat.

This is one of the very few times that methods have been actually removed from the public API of the JDK (after all, even the highly dangerous `Thread.stop` is still present, despite having been deprecated since Java 1.1). Removing methods is a very rare event and shows the importance of a good modularity solution to the Java team.

A First Look at Modules

Let's have a look at how things have changed in the Java 9 (Jigsaw) EA release:

```
$ cd $JAVA_HOME
$ pwd
/java9/Contents/Home
$ ls -lh
total 42640
-r--r--r--    1 10  143    3.2K COPYRIGHT
-r--r--r--    1 10  143    40B LICENSE
-r--r--r--    1 10  143   158B README.html
-r--r--r--    1 10  143   174K THIRDPARTYLIC...txt
drwxr-xr-x   46 10  143    1.5K bin
drwxr-xr-x    7 10  143    238B conf
drwxr-xr-x    9 10  143    306B db
drwxr-xr-x   12 10  143    408B demo
drwxr-xr-x   11 10  143    374B include
-rw-r--r--    1 10  143   127K jrt-fs.jar
drwxr-xr-x   84 10  143    2.8K lib
-rw-r--r--    1 10  143    549B release
drwxr-xr-x   15 10  143    510B sample
-rw-r--r--    1 10  143    21M src.zip
```


[In order to fit, some minor file information has been removed from this listing. —*Ed.*]

There are a few things to see here, but let's start with the big news—the `jre` directory is gone. There is no more `rt.jar` to contain the whole of the JRE. Instead, the JRE is stored in the new *jimage* format. This is a container format that manages classes and resources needed by the modularized runtime.

Rather than traditional zip-based compression, jimage files are indexed to support fast lookup of classes and resources. The content region of a jimage contains all classes and resources for the image and is managed in terms of locations.

Resources can be located in the index by using a module path as a search key. The path format is `/<module-name>/<package>/<base-name>.<extension>`. Paths are versioned, and the current path is “9.0”—this reflects the current release of the JVM.

The main jimage file is found in `lib/modules` and is called `bootmodules.jimage`. However, in addition to the jimage files there are also .jmod files—Java modules. These files are being used as a test bed for other module features outside of the efforts in .jimage to speed up access. As it stands now, .jmod files are still implemented as zip files, but the format will almost certainly change in future. The fact that there are two packaging formats shows how much of a moving target Java 9 modules really are at present.

The `java.base.jmod` file contains the minimal viable collection of classes for any nontrivial Java program to run. It contains the following packages (or subsets of them):

```
java.io
java.lang
java.math
java.net
java.nio
java.security
java.text
java.time
```

```
java.util
javax.crypto
javax.net
javax.security
```

The rest of the module consists of the implementation classes to support the base module. Of course, the real intent of Project Jigsaw is that Java developers also make use of the mechanism to produce modular libraries and applications of their own. Let's take a quick look into this world by considering a simple "Hello World" for modules.

A simple Java module. To create a very simple Java module, we need to write two parts, the first of which is a simple core class such as this:

```
package com.jdk9ex;

public class Main {
    public static void main(String[] args) {
        System.out.println("Hello Modules!");
    }
}
```

In Java 8 and earlier, this code could be compiled and run without further ceremony. However, to run correctly in modular Java, this needs to be supplemented with a new piece of metadata: a `module-info.java` file.

The intention is that this file will become a fairly sophisticated metadata provider and handle versioning and other important features of modules, but the currently shipping version in Jigsaw EA is quite primitive and is only intended to allow keen developers to start investigating module technology.

The simplest module looks like this (assuming our module for JDK 9 examples is named `com.jdk9ex`):

```
module com.jdk9ex { }
```

Eagle-eyed developers will note that this means that `module` is a new keyword in Java 9. For this to compile, the directory structure needs to be laid out according to the new modular source rules. For our module `com.jdk9ex`, this structure is the following:

```
| ____src
| | ____com.jdk9ex
| | | ____com
| | | | ____jdk9ex
| | | | | ____Main.java
| | | | | module-info.java
```

Note that the module name is independent of the normal conventions for Java packages that live inside the module. To compile this modular code, we need to tell `javac` that we're running a module-aware build:

```
$ javac -d modules/com.jdk9ex \
    src/com.jdk9ex/module-info.java \
    src/com.jdk9ex/com/jdk9ex/*
```

This produces a set of modular class files, but not a jimage. To execute this code, we also need to explicitly inform the JVM that modules are needed:

```
$ java -modulepath modules -m \
    com.jdk9ex/com.jdk9ex.Main
Hello Modules!
```

The basic “Hello World” example is an established pattern for programmers, and experimenting with the modules system and seeing how it works is highly recommended for developers who want to fully understand the current state of modularity for Java 9.

What could go wrong? Inevitably, some aspects of any new technology will cause problems for early adopters, so let's look at a couple of basic failure cases. In particular, if you fail

to build or invoke modular Java correctly, you might see a new sort of exception:

```
$ java -modulepath modules -m com.jdk9ex.Main
Error occurred during initialization of VM
java.lang.module.ResolutionException:
    Module com.jdk9ex.Main not found at
java.lang.module.Resolver.fail
    (java.base@9.0/Resolver.java:880)at
java.lang.module.Resolver.resolve
    (java.base@9.0/Resolver.java:193)at
java.lang.module.Resolver.resolve
    (java.base@9.0/Resolver.java:173)at
java.lang.module.Configuration.resolve
    (java.base@9.0/Configuration.java:229)at
jdk.internal.module.ModuleBootstrap.boot
    (java.base@9.0/ModuleBootstrap.java:174)at
java.lang.System.initPhase2
    (java.base@9.0/System.java:1242)
```

[Some lines have been wrapped to fit. —*Ed.*]

This single stack trace shows that we have the following new items:

- Packages, including `java.lang.module`
- Exceptions, including `ResolutionException`
- Locations for code, such as
`java.base@9.0/ModuleBootstrap.java`
- Entry points for startup, such as
`java.lang.System::initPhase2`

From this we can also see that the new modular paths used for `jimages` are now directly present in stack traces.

Alternatively, we might try to access an internal implementation class. The code shown below compiles and runs on Java 8:

```
import sun.invoke.util.BytecodeName;

public class InternalsCheck {
```

```
public static void main(String[] args) {
    String bName =
        BytecodeName
            .toBytecodeName("java.lang.Object");
    System.out.println(bName);
}
```

As expected, it produces the internal name for `java.lang.Object`. However, with modules, access to the implementation class is restricted, and this code will no longer even compile:

```
$ javac -d modules/com.jdk9ex \
    src/com.jdk9ex/module-info.java \
    src/com.jdk9ex/com/jdk9ex/*

src/com.jdk9ex/com/jdk9ex/InternalsCheck.java:8:
error: package sun.invoke.util does not exist
import sun.invoke.util.BytecodeName;
                        ^
src/com.jdk9ex/com/jdk9ex/InternalsCheck.java:12:
error: cannot find symbol
    String bName = BytecodeName.
toBytecodeName("java.lang.Object");
                  ^
symbol:    variable BytecodeName
location: class InternalsCheck

2 errors
```

These errors demonstrate the strong guarantees of API integrity that are one of the goals of the Java module system. As it stands, `javac` has been upgraded to prevent access to the implementation class `BytecodeName`, but IDEs and other tools within the Java environment do not yet acknowledge this new reality—one more sign that there’s a long way to go before JDK 9 is ready for the general population of developers.

The good news is that all of the major IDE vendors are actively working on new versions to fully support Java 9. For example, Oracle has announced that NetBeans 9 will be focused on JDK 9 support, and Eclipse's JDT now has all active development happening on a JDK 9 branch.

A word about Unsafe. From the point of view of the Java platform developers, especially those involved in the OpenJDK project, “shotgun privacy” is a significant problem. While the java and javax packages are protected by the “prohibited package” SecurityException mechanism, this does not apply to the internal implementation classes.

Java libraries and frameworks are not supposed to couple directly to these implementation details. The attitude of Java's stewards has always been that to do so is dangerous, and no attempt will be made to accommodate developers who break the rules and link to internal details.

Despite repeated admonitions, many popular Java libraries break the rules and access the internals of the platform. This is a big problem, because it leaves the JDK developers in a very difficult situation.

One choice is to concede that some internals have become a de facto part of the API, support them, and accept that it is now very difficult to make changes that prevent those internals from being accessed. Another choice is to change internals and, thus, affect or break libraries and frameworks that millions of production applications rely on.

The most famous, widely used, and dangerous example of this direct coupling is the `sun.misc.Unsafe` class. This class represents a major pressure point in the adoption of

Many popular Java libraries break the rules and access the internals of the platform. This is a big problem, because it leaves the JDK developers in a very difficult situation.

a modules system. If access to `Unsafe` were simply shut off in JDK 9, this would prevent almost all Java applications from upgrading, because basically any nontrivial application will use a library that relies, directly or indirectly, on functionality in `Unsafe`.

However, indefinite access to **Unsafe** risks making it into an unofficial, de facto standard, and removes the possibility of evolving internal platform mechanisms. The middle path agreed to between Oracle and the Java community is that temporary access will be provided for Java 9, but it is expected that access will be removed (and replaced with standardized, supported equivalent functionality) in Java 10.

This means that Java developers will have an easier path to upgrading to Java 9, because existing frameworks will continue to work. Library and framework developers will need to migrate to the new mechanisms in time for Java 10, which is not likely to ship until 2018.

What will developers need to do differently? Java developers will need to adapt to a new way of packaging and deploying code to get the most out of the new functionality. The good news, though, is that there's no need to start doing that straight-away. The traditional methods using JAR files will continue to work until such time as teams are ready to adopt the modular way of working.

One simple approach (which teams can use even before Java 9 arrives) is to make use of the Compact Profiles that shipped as part of Java 8. This was a first step toward modularity and defines three separate profiles that are true subsets of the JRE. The smallest profile, compact1, is around 11 MB, which saves a significant amount of space.

Although the early-access previews do not contain all expected functionality, **there is still plenty for you to explore in the work in progress.**

Applications that can run in a smaller profile than the full JRE will have a much easier time converting to a modular world. In many cases, it will be worth doing some up-front work now to make life easier later. Also, understanding and documenting application dependencies is a worthwhile exercise in the reduction of technical debt.

Conclusion

The advent of modules is a large change in the Java environment, probably one of the biggest ever. Although the early-access previews do not contain all expected functionality, there is still plenty for you to explore in the work in progress. The release of Java 9 is months away, and the feedback of developers who have tried Java 9 EA in real-world tests is very welcome. The [OpenJDK Adoption group](#) is the ideal place for interested developers to contribute their feedback and find out what they can do to help move Java 9 modules forward. </article>

Ben Evans helps to run the London Java Community and represents the user community as a voting member on Java's governing body—the JCP Executive Committee. He is the author of *The Well-Grounded Java Developer*, the new edition of *Java in a Nutshell*, and the forthcoming *Optimizing Java*.

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JDK 9 outreach

Using Modularity (video presentations from Devovx)

The JDK 9 schedule of release

How version strings will appear in JDK 9



SCOTT MCKINNEY

Gosu: A Modern, Down-to-Earth Language for the JVM

A low-ceremony language used in large enterprise apps offers an extraordinarily flexible, yet static, type system.

Gosu is about 13 years old. It began as a simple scripting language here at Guidewire Software late in 2002. We needed a straightforward language for our customers to customize our products. Our basic criteria for the language included that it be Java interoperable, statically typed, familiar, and easy to use. Static typing facilitates our larger goal to provide a safe and pleasurable user experience via deterministic tooling such as rich parser feedback, code completion, refactoring, usage searching, and so forth. We would much rather have pulled a language from the shelf than build our own, but at the time, there weren't any scripting languages available that came close to satisfying our needs. As a fledgling startup, we weren't about to compromise at this critical stage; Guidewire's success would be won at least in part on our customers' ability to tailor our products using our language and tools. As a result, Gosu came to life.

Since then, we've come a long, long way. With more customers came demand for more Gosu features, which over time led Gosu to become a powerful, general-purpose programming language. Thus, unlike many programming languages, nearly every step of Gosu's development is a result of true pragmatism—its features were developed and refined for broad usability and have been vetted in the field by hundreds of medium to very large, international corpo-

rations employing thousands of developers writing mission-critical software with Gosu.

Hello

Getting down to business, you are probably more interested in Gosu’s capabilities and syntax than in its history, so let’s get to it. Here is Gosu’s “Hello, World!”:

```
print("Hello, World!")
```

That's it. Because Gosu is inherently scriptable, there is no need for boilerplate code, such as a `Main` class or `main` method. But if you're feeling nostalgic, this also works:

```
class RunMe {
    static function main(args: String[]) {
        print("Hello, World!")
    }
}
```

This class prints “Hello, World!” to the console. The same holds for the former, simpler example. So in addition to conventional class files, Gosu supports *program* source files that are free-form scripting files. You can code up anything in a program, including statements, functions, whole classes, whatever—in any arrangement you like.




```
if(location != null) {
    return location.Address
}
else {
    return null
}
```

```
return location?.Address
```

```
function printList(list: List<String>,
                  separator: String = ", ")
printList(myList)
printList(myList, " | ")
```

```
function configure(lux=false, awd=false, ac=false)
configure(:awd = true)
```

```
var range = "A".. "M"
print(range.contains("Jones")) // true
print(range.contains("Smith")) // false
```

```
for(i in 1..10) {  
  print(i)  
}
```

```
// A biweekly date sequence
var span = (date1..date2).step(2).unit(WEEKS)
```

```
10..1 // reverse order
start..end // start inclusive, end exclusive
```

```
interface ClipboardPart {
    function cut()
    function copy()
    function paste()
}
class MyWindow extends Window
    implements ClipboardPart {
    delegate _myPart represents ClipboardPart =
        new ClipboardPartMixin(this)
}
```

Basically, this delegate statement hooks up the `ClipboardPartMixin` with `MyWindow`'s implementation of `ClipboardPart`. No other work is necessary; all `ClipboardPart` methods automatically forward to the delegate. No more boilerplate compositional code!

Blocks (aka closures). In appearance, Gosu blocks are similar to Java lambdas:

```
var list = {"Pascal", "Java", "Gosu"}
var lengths = list.map(\ e -> e.length)
```

As you can see, Gosu blocks begin with a `\` instead of Java's `()`; otherwise the syntax is nearly identical. Under the hood, however, things are quite different. For starters, Gosu blocks are true closures. Basically, this means that they can access and modify any variables from the local scope. But what really distinguishes a block from a lambda is that it has its own type, the `Function` type. There is no need for functional interfaces (or SAMs) as a go-between in Gosu, because the `Function` type is a first-class type:

```
var capitalize(String):String = \s -> s.capitalize()
```

or

```
var capitalize = \s: String -> s.capitalize()
```

You can use `Function` types anywhere. For instance, you can use `Function` types directly in a function's parameter list:

```
function visitThings(consumer(Thing))
```

And you can use them with generics:

```
var listeners: Set<block(Event)>
```

`Function` types are 100 percent interoperable with Java 8 functional interfaces. You can pass a block to a functional interface and pass a functional interface to a `Function` type. **Generics.** Gosu generics use array-style covariance by default. For instance, the following assignment is legal in Gosu:

```
var list: List<Object> = new ArrayList<String>()
```

While this is technically unsound, it works the way most programmers think. So, unlike Java, Gosu does not have wildcards or any type of use-site variance. In our experience, use-site variance is a significant source of confusion, which leads to misuse and circumvention of generics via casting and other techniques. Fundamentally, type safety exists to help programmers read and write better code; it shouldn't get in the way.

Alternatively, if you don't want array-style variance for your generic class, you can make it fully typesafe using C# style `in/out` variance modifiers in your type variable declarations. For instance, typesafe `Consumer` and `Producer` interfaces can be defined like so:

```
interface Consumer<in T> {
    function apply(t: T)
}
interface Producer<out T> {
    function get(): T
}
```

Generally, stuff returned *out* of a function is covariant while stuff passed *in* to a function is contravariant. Gosu verifies usage of `in/out` type variables against a more sophisticated version of these basic rules. Note that if you mix a default generic type with an `in/out` type, Gosu *infers* the variance of the default type and checks whether it's compatible:

```
// error: T is used in an 'out' position in Callable
interface Listener<in T> extends Callable<T> {
    function someEvent(t: T)
}
```

Here Gosu infers the variance of `Callable`'s `T` as "out" and reports the incompatibility. Gosu infers variance of both Gosu and Java types, including usage of wildcards inside Java types.

Another useful aspect of Gosu generics: type arguments persist at runtime. In technical speak, Gosu employs type



reification as opposed to Java's type *erasure*. This means that the following code does what you expect:

```
var foo = new Foo<String>()
print(typeof foo) // prints Foo<String>
```

This cannot be done in Java, because of the type erasure.

Enhancements. An *enhancement* is a Gosu type that defines new functions and properties for an existing type. Enhancements live in separate source files such as classes; there is no need to import them. Here is a simple String enhancement:

```
enhancement MyStringEnhancement : String {
  function print() {
    print(this)
  }
}
```

Now you can tell a String to print itself:

```
"Echo".print()
```

Gosu provides a host of useful enhancements for most of the Java runtime library—tons of refreshing features for Collections, Iterable, String, and so on.

Structures. Sometimes we need a way to make a type satisfy an interface. For example, Java's Rectangle, Point, and Component classes all have X, Y coordinates accessible by identically named methods:

```
class Rectangle {
    public double getX();
    public double getY();
    ...
}
```

```
class Point {
    public double getX();
```

```
public double getY();
    ...
}
```

```
class Component {
    public int getX();
    public int getY();
    ...
}
```

Yet they do not share a common interface for accessing the coordinate. Using nominal typing, there is no way to extract an interface for these classes: we can't modify them to implement a `Coordinate` interface. This is where structural typing comes in handy:

```
structure Coordinate {
  property get X(): double
  property get Y(): double
}
```

```
var sorter = \ c1: Coordinate,
               c2: Coordinate -> {
  var delta = c1.Y == c2.Y
              ? c1.X - c2.X
              : c1.Y - c2.Y
  return delta < 0 ? -1 : delta > 0 ? 1 : 0
}
```

```
var points: List<java.awt.Point> =  
    {new(2, 1), new(3, 5), new(1, 1)}
```

```
points.sort(sorter)
```

The `Coordinate` structure is just like an interface, but Gosu determines assignability from its methods and properties instead of forcing a class to implement it nominally. So in this example, because `Point` satisfies the *structure* of `Coordinate`, it is considered structurally assignable to it.

code completion, usage searching, “go to feature” navigation, refactoring, code formatting, code inspections, comprehensive debugger, incremental compiler, Scratchpad editing, and more. [Download it for free.](#)

We've also recently released full support for building Gosu projects with Maven and Gradle. We use these tools ourselves to build and distribute Gosu and supporting projects.

Open Source

Gosu is a very active, fully open source language, found on [GitHub](#). There you'll see that we're also currently working on some interesting projects to support an ecosystem for Gosu. Notable among them is [SparkGS](#), a simple yet powerful web application framework for Gosu.

Conclusion

Guidewire's internal need for a straightforward static language to build and drive our applications ultimately led to the development of a powerful, pragmatic language. We feel that Gosu is uniquely positioned as both a powerful modern OOP language and as a concise scripting language. You can write small scripts and quickly execute them from source or, as several enterprise customers have done, write Gosu applications that exceed 1 million lines of code. As a fully open source project and now with support for open tooling such as IntelliJ Community Edition, Maven, and Gradle, we invite you to try Gosu in one of your projects or for a fun afternoon of scripting. Enjoy! [</article>](#)

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MANCHESTER JAVA COMMUNITY



Formed in May 2013 by Alison McGreavy, the Manchester Java Community (MJC) is the nexus for the city's Java community. Currently led by McGreavy, Debbie Roycroft, and Roberto Nerici, the MJC has grown from four members at the first meeting to more

than 300 members. Meetings are held typically once a month at venues such as [MadLab](#), and draw on average 30 people. The members come mainly from the Manchester, UK, area, but some from as far away as Liverpool and Leeds. Sessions range from lightning talks and hands-on instruction to guest presentations. Over the last two years, topics have included core Java, Java frameworks, tooling, JVM languages, and the JVM itself. These sessions have encouraged homegrown speakers and have attracted some great guest speakers such as the London Java Community's Ben Evans, the Ceylon team from Red Hat, and Heinz Kabutz. The MJC is a member of the JCP and will also be running a Java 9 Hack event in January 2016.

The MJC has great links with the wider programming community, both in Java events such as JavaOne and Devoxx and through the general tech community in Manchester. It is keen on developing more.

If you plan to be in the Manchester area and would like to participate in an MJC event, check out the [Manchester Java Community on Meetup.com](#) or on Twitter [@mcrcjava](#).

- 8092:8092
- 8093:8093
- 11210:11210

This file has one service, `mycouchbase`, which uses the prebuilt image `couchbase/server` defined by the `image` key. Volume mapping is done using the `volumes` key, and port forwarding is done using the `ports` key. The key name/values are analogous to their `docker run` counterpart, as shown on the previous page.

The complete syntax for the Compose file is explained at the [Docker site](#).

Now, you can start the Couchbase database container by running the following command:

```
docker-compose up -d
```

This command starts the service `mycouchbase` (in the background because of the `-d` switch) and the Couchbase container in this service.

A list of common commands that can be used with Compose is shown in **Table 1**.

You can display the complete list of commands using the command `docker-compose --help`.

COMMAND	PURPOSE
up	CREATE AND START CONTAINERS
stop	STOP SERVICES
rm	REMOVE STOPPED CONTAINERS
ps	LIST CONTAINERS
logs	VIEW OUTPUT FROM CONTAINERS
scale	SET THE NUMBER OF CONTAINERS FOR A SERVICE

Table 1. Common commands used in Compose

Docker Compose becomes more relevant and interesting when multiple services need to be started for an application, which is generally the case. As an example, if your application consists of one WildFly service and one Couchbase service, then the Compose file would look like this:

```
mycouchbase:
  container_name: "db"
  image: couchbase/server
  volumes:
    - ~/couchbase:/opt/couchbase/var
  ports:
    - 8091:8091
    - 8092:8092
    - 8093:8093
    - 11210:11210
mywildfly:
  image: arungupta/wildfly-admin
  environment:
    - COUCHBASE_URI=db
  ports:
    - 8080:8080
    - 9990:9990
```

This application uses two services, `mycouchbase` and `mywildfly`. The `mycouchbase` service starts the Couchbase server. It has an additional attribute, `container_name`, that specifies a custom container name instead of a generated default name. The `mywildfly` service starts the WildFly application server. The default WildFly image exposes only port 8080 for the application to be accessed. The custom image, `arungupta/wildfly-admin`, starts WildFly such that the management interface is bound to all network interfaces. It also exposes port 9990, which can then be used for deploying applications. In addition, it also has an environment variable, `COUCHBASE_URI`, that is then used in applications deployed on WildFly to access the database. I'll provide more detail about this a little later (when the application environment is started).

(the default), `binpack`, and `random`—can be applied to pick the best node to run your container. The default strategy optimizes the node for the least number of running containers.

- **Node discovery service.** The swarm manager talks to a hosted discovery service. This service maintains a list of IP addresses in the swarm cluster. The Docker hub hosts a discovery service that can be used during development. In production, the default discovery service is replaced by other services such as etcd, Consul, or ZooKeeper. You can even use a static file.
- **Standard Docker API.** Docker Swarm serves the standard Docker API. Thus, any tool that talks to a single Docker host will seamlessly scale to multiple hosts now. This means that if you were using shell scripts utilizing the Docker CLI to configure multiple Docker hosts, the same CLI can now talk to a Docker Swarm cluster.

Deploying a multicontainer Java application that uses Couchbase for a Docker Swarm cluster that spans multiple hosts requires the following steps:

1. Create the discovery service.
2. Create the Docker Swarm cluster.
3. Start the application environment.
4. Configure the Couchbase server and load sample data.
5. Deploy the application to the Docker Swarm cluster.

Docker Swarm takes care of the distribution of deployments across the nodes.

Figure 2 provides a conceptual overview of different components in the application:

- The cluster has two nodes: one master and another worker node.
- Docker Compose is used to start the application environment on the cluster.
- The discovery service is hosted on a separate machine outside the cluster.

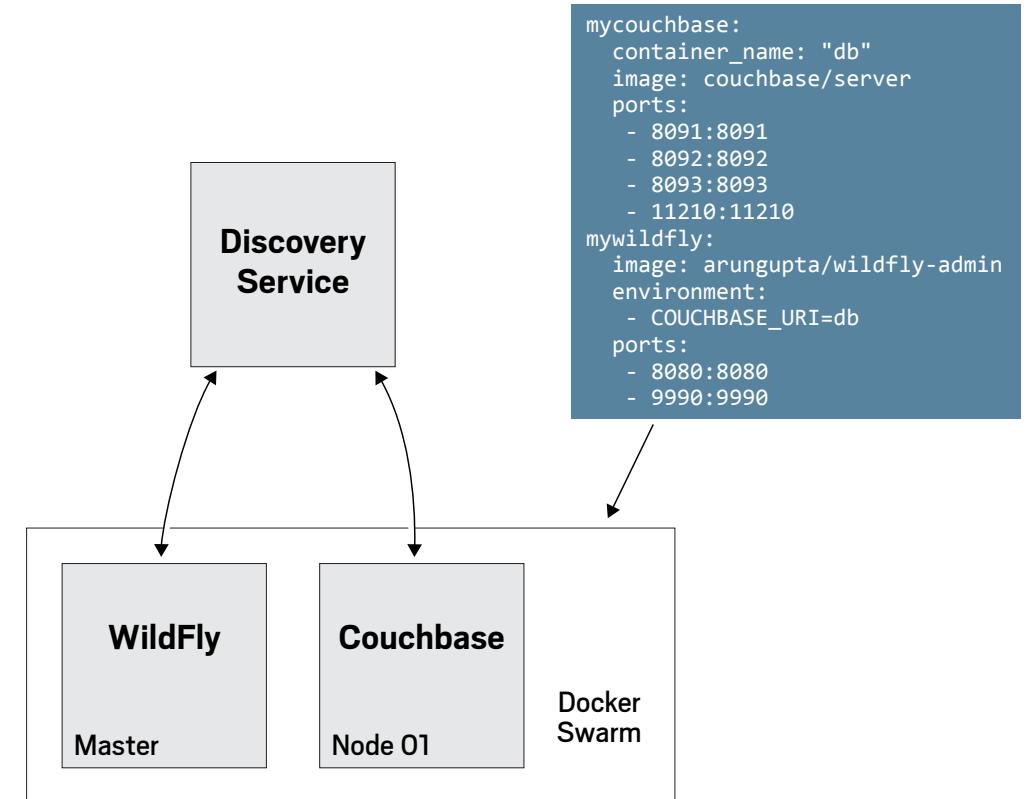


Figure 2. A simple service running on a Docker Swarm

Maven is used to configure Couchbase and deploy the application to WildFly. **Note:** This article uses WildFly and Couchbase. But you can easily use Tomcat, GlassFish, or any other application server. Similarly, you can use any other database server such as MySQL or JavaDB. Naturally, the image and the included application would need to be updated accordingly.

Let's dig into the details of how to set this up.

Create the Discovery Service

I will use [Consul](#) for the discovery service, although other similar tools, such as etcd and ZooKeeper, can be used instead.

First, create a new Docker machine that will host the discovery service:


```
docker-machine create -d=virtualbox consul-machine
```

Then connect to this machine:

```
eval $(docker-machine env consul-machine)
```

Run the Consul service using the following Compose file:

```
myconsul:
  image: progrium/consul
  restart: always
  hostname: consul
  ports:
    - 8500:8500
  command: "-server -bootstrap"
```

Start this service using `docker-compose up -d`. You can verify the started container using the `docker ps` command described in the first part of this article.

Create the Docker Swarm Cluster

Docker Swarm is fully integrated with Docker Machine, and so it is the easiest way to get started. Create a swarm master and point to the Consul discovery service:

```
docker-machine create -d virtualbox
--virtualbox-disk-size "5000" --swarm
--swarm-master --swarm-discovery=
"consul://$(docker-machine ip consul-machine)
:8500" --engine-opt="cluster-store=consul://$(
docker-machine ip consul-machine):8500"
--engine-opt="cluster-advertise=eth1:2376"
swarm-master
```

The following are the meanings of these switches:

- `--swarm` configures the machine with Docker Swarm.
- `--swarm-master` configures the created machine to be the swarm master.

- `--swarm-discovery` defines the address of the discovery service.
- `--cluster-advertise` advertises the machine on the network.
- `--cluster-store` designates a distributed key/value storage back end for the cluster.
- `--virtualbox-disk-size` sets the disk size for the created machine to 5 GB. This is required so that the WildFly and Couchbase images can be downloaded onto any of the nodes.

You can get more information about this machine by running the `inspect` command. If you run it, you'll see that the disk size is indeed 5 GB.

Now, create a new machine to join this cluster:

```
docker-machine create -d virtualbox
--virtualbox-disk-size "5000" --swarm
--swarm-discovery=
"consul://$(docker-machine ip consul-machine):
8500" --engine-opt="cluster-store=consul://$(
docker-machine ip consul-machine):8500"
--engine-opt="cluster-advertise=eth1:2376"
swarm-node-01
```

Notice that no `--swarm-master` option is specified in this command, which ensures that the created machine is a *worker* node.

If you list all the created machines, you will see the contents of **Table 2**. The machines that are a part of the cluster have the cluster's name in the SWARM column; otherwise, that column is blank for machines that are not part of the cluster. For example, `consul-machine` is a standalone machine, whereas all the other machines are part of the `swarm-master` cluster. The swarm master is also identified by `(master)` in the SWARM column.

Connect to the swarm cluster and find some information about it:

NAME	ACTIVE	DRIVER	STATE	URL	SWARM
consul-machine	-	virtualbox	Running	tcp://192.168.99.100:2376	
swarm-master	*	virtualbox	Running	tcp://192.168.99.101:2376	swarm-master (master)
swarm-node-01	-	virtualbox	Running	tcp://192.168.99.102:2376	swarm-master

Table 2. The contents of the sample Docker Swarm

```
eval "$(docker-machine env --swarm swarm-master)"
docker info
```

Note that `--swarm` is specified to connect to the swarm cluster. Otherwise, the command will connect to the `swarm-master` machine only.

The `docker info` command provides detailed output about the different nodes and the number of containers running on each node. The first part of the output provides a summary and is shown below:

```
docker info
Containers: 3
Images: 2
Role: primary
Strategy: spread
Filters: health, port,
        dependency, affinity, constraint
```

There are two nodes: one swarm master and one swarm worker node. There are three containers running in this cluster: one swarm agent on the master and each node, and there is an additional swarm-agent-master running on the master.

Start the Application Environment

The cluster is now ready, and our application can be deployed to it. This Java EE application deployed on WildFly will provide a CRUD/REST interface to the data in Couchbase.

I will use the Compose file shown earlier to start the application environment. But before I start, let's look at the current state of the network in the cluster.

By default, Docker creates three networks for each host, as shown in Table 3.

Docker allows you to create *bridge* and *overlay* networks. Bridge networks span a single host, and overlay networks span multiple hosts. The Docker Compose application can be started with the `--x-networking` switch. In this case, a bridge network is created for a single host and an overlay network is created for a swarm cluster.

Make sure you are connected to the cluster by running the following command:

```
eval "$(docker-machine env --swarm swarm-master)".
```

I will use the Compose file shown earlier to start WildFly and Couchbase. In the WildFly service, the `COUCHBASE_URI` environment variable is set to `db`. And this is the name of the Couchbase container. Start the application with

NETWORK NAME	PURPOSE
bridge	DEFAULT NETWORK THAT CONTAINERS CONNECT TO
none	CONTAINER-SPECIFIC NETWORKING STACK
host	ADDS THE CONTAINER ON THE HOST'S NETWORKING STACK

Table 3. Three networks created by Docker

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using the `docker-machine ip swarm-node-01` command and then access the application in your browser.

This application supports GET, PUT, POST, and DELETE APIs for resources in the Couchbase sample data. The complete list of REST APIs for this application is [documented online](#).

Conclusion

This two-part series explained how to deploy a Java application on Docker. The first part introduced the basic concepts of Docker and the Docker Toolbox. I then discussed how to build an image and run a container. Those basics will apply to almost all Docker projects.

This second part introduced Docker Compose and Docker Swarm to help build multicontainer applications that can be deployed on multiple hosts. In the process, I touched on how Docker networking provides isolated environments for different applications. This should provide what you need to get started using multiple Docker containers in your application.

Docker nicely complements Java’s “write once, run anywhere” mandate, because it enables “package once, deploy anywhere.” The huge ecosystem that has built up around Docker in the past few years is driven by Docker’s simplicity. With a little experimenting, I expect you will be equally excited about packaging Java applications using Docker. [</article>](#)

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Getting Started with Docker



TILEN FAGANEL AND
MATJAZ B. JURIC

KumuluzEE: Building Microservices with Java EE

Develop self-contained microservices with standard Java EE APIs using the open source KumuluzEE framework.

In this article, we explore how to develop microservices with standard Java EE APIs. Microservices have become an important architectural style for developing complex applications composed of small, independent services deployed as individual processes. These services communicate through well-defined APIs. Each microservice is self-contained; is responsible for a single task; is accessible through a lightweight API, such as REST; and has its own lifecycle. Microservices result in a highly decoupled, modular, and reusable architecture for composite applications.

Developing microservices in Java means that not only is the application designed around REST services, but also that each service, the front end, and other components are deployed separately and independently. In other words, instead of packing all the services, business logic, front end, and other modules into a single EAR file and deploying it as a monolith, microservices use individual archives (such as JAR files) for each component. The [KumuluzEE framework](#), as we'll see shortly, automates the tasks related to the configuration and deployment of microservices, specifically on Java EE. **[Note:** KumuluzEE won the Duke's Choice Award at the 2015 JavaOne conference. —*Ed.*]

Microservices with Java EE

Suppose we want to create an online train-reservation ser-

vice people can use to plan their route and buy their tickets. For brevity, we are going to look at a simplified version of this example; it will allow only viewing routes and booking a route via a simple user interface.

Using the traditional approach, we would create a monolithic EAR package that would include our business logic, services, and one or more WAR packages containing the front end. We would deploy the EAR file to an application server, such as Oracle WebLogic Server or GlassFish.

In contrast, using the microservice architecture, we start by separating the responsibilities. Routes, the booking service (reservations), and the UI become three separately developed, configured, and deployed microservices. They are stateless and communicate through REST interfaces—although we could also use SOAP or remote method invocation (RMI). In this way, we create microservices that are domain-defined and follow the “single responsibility” principle with regard to explicit interfaces. We have created a highly modular, decoupled architecture, where each service is responsible for a single, dedicated piece of functionality. Also, each microservice has its own lifecycle. The proposed architecture using microservices is shown in **Figure 1**.

In the remainder of this article, we use this simplified example. But keep in mind that microservices are best suited for complex applications and systems.



projects—each containing its own microservice. For brevity’s sake, we will create them in the same repository. We will create a `routes` project for the route calculation service, a `bookings` project for the booking service, and a `ui` project for the front end. We will also add a module that will hold our JPA entities (`models`) and a module that will hold our `utils`, because they will be shared with our three microservices. **Note:** In real-world projects, it is generally recommended to use a separate repository for each microservice so that they are treated as separate entities and have separate versioning and revision history as well as separate deployment.

We will also create the topmost `pom.xml` file. You can look at the project structure and the `pom.xml` file by downloading the source code for this project from [GitHub](#).

To create our microservice projects, we will use Maven archetype generation (`mvn -B archetype:generate`) for all modules. This will generate the three projects we require.

Adding KumuluzEE

Now we need to add the appropriate dependencies to the KumuluzEE framework. KumuluzEE is completely modular, which means that apart from the core functionality each Java EE component is packaged as a separate module and must be included explicitly as a dependency in order to be used. KumuluzEE will automatically detect which modules are included in the classpath and properly configure them.

We include KumuluzEE by defining the appropriate dependency in Maven. It is recommended that we define a property with the current version of KumuluzEE and use it with every dependency:

```
<properties>
  <kumuluzee.version>
    2.0.0
  </kumuluzee.version>
</properties>
```

Adding the Front-End UI Service

Let's start with the `ui` microservice and include the core KumuluzEE module for bootstrapping the logic and configuration. It provides the `com.kumuluz.ee.EeApplication` class with the `main` method that will bootstrap our app. We will also include the `servlet` and the HTTP server. We will use a Jetty servlet implementation, which is known for its high performance and small footprint. The `./ui/pom.xml` file contains this:

```
<dependency>
  <groupId>com.kumuluz.ee</groupId>
  <artifactId>kumuluzee-core</artifactId>
  <version>${kumuluzee.version}</version>
</dependency>
<dependency>
  <groupId>com.kumuluz.ee</groupId>
  <artifactId>kumuluzee-servlet-jetty</artifactId>
  <version>${kumuluzee.version}</version>
</dependency>
```

We must also include the `maven-dependency-plugin` in our `pom.xml` file, which will copy all our dependencies together with the classes. So we add the following to the `./ui/pom.xml` file:

```
<plugin>
  <groupId>org.apache.maven.plugins</groupId>
  <artifactId>maven-dependency-plugin</artifactId>
  <version>2.10</version>
  <executions>
    <execution>
      <id>copy-dependencies</id>
      <phase>package</phase>
      <goals>
        <goal>copy-dependencies</goal>
      </goals>
    </execution>
  </executions>
</plugin>
```

```
<dependency>
  <groupId>com.kumuluz.ee</groupId>
  <artifactId>kumuluzee-jpa-eclipselink
  </artifactId>
  <version>${kumuluzee.version}</version>
</dependency>
```

```
@Entity
@NamedQuery(name="Route.findAll",
            query="SELECT r FROM Route r")
public class Route {

    @Id
    @GeneratedValue(strategy =
        GenerationType.IDENTITY)
    private Integer id;

    private String name;

    private String start;

    private String end;
```



```

        .getResultList();

    return Response.ok(bookings).build();
}

...

@POST
public Response createBooking(Booking b) {
    em.getTransaction().begin();
    em.persist(b);
    em.getTransaction().commit();
    return Response.status(
        Response.Status.CREATED)
        .entity(b).build();
}
}

```

As you can see, with KumuluzEE the microservice implementation does not require any modifications and is exactly the same as with any other Java EE application. You can implement the remaining microservices the same way or look at the provided sample code.

Handling Service Discovery

Let's suppose that we are using JavaServer Faces (JSF) for the front-end UI module. From there, we will be calling our microservices via REST to receive or save the actual data. The main problem with this is that we need to know the exact URLs of the microservices. We could pass the URLs via environment variables. However, that approach would require manual updating every time anything changes. And in the cloud, these changes can be quite frequent.

A better solution would be to dynamically query the address of the requested microservice. We will use Apache ZooKeeper for service discovery, but we could also use any similar tool. In short, ZooKeeper is a centralized service for maintaining configuration information. We will use it to store the

correct URL to each microservice. We add a helper class, `ServiceRegistry`, in our `utils` module to handle the dynamic registering, unregistering, and retrieval of endpoints with ZooKeeper:

```
@ApplicationScoped
public class ServiceRegistry {

    private final CuratorFramework zookeeper;
    private final
        ConcurrentHashMap<String, String> zonePaths;

    @Inject
    public ZooKeeperServiceRegistry()
        throws IOException {
        try {
            String zookeeperUri =
                System.getenv("ZOOKEEPER_URI");
            zookeeper = CuratorFrameworkFactory
                .newClient(zookeeperUri,
                    new RetryNTimes(5, 1000));
            zookeeper.start();
            zonePaths = new ConcurrentHashMap<>();
        } catch (IOException) {
            ...
        }
    }

    public void registerService(
        String name, String uri) {
        try {
            String node = "/services/" + name;
            if (zookeeper.checkExists()
                .forPath(node) == null) {
                zookeeper.create()
                    .creatingParentsIfNeeded()
                    .forPath(node);
            }
            String nodePath =
                zookeeper.create().withMode(
```

```

        CreateMode.EPHEMERAL_SEQUENTIAL)
        .forPath(node + “/_”,
            uri.getBytes());
        zonePaths.put(uri, nodePath);
    } catch (Exception ex) {
        ...
    }
}

// ... Similar for the other methods.
// See full example available for download.
}

```

The `ZOOKEEPER_URL` environment variable should contain our ZooKeeper URL. We will be starting a ZooKeeper service alongside our microservices using Docker, which is discussed in the next section. Also make sure that the `utils` package is added as a dependency to every microservice.

We can now inject the service above into our microservices to register its URL upon startup and unregister it upon shutdown. One way to do this is to add a bean to our `booking` microservice to handle this task dynamically:

```
@ApplicationScoped
public class BookingService {

    @Inject
    ServiceRegistry services;

    private String serviceName = "trains-booking";
    private String endpointURI;

    public BookingService() {
        endpointURI =
            System.getenv("BASE_URI");
    }

    @PostConstruct
    public void registerService() {
```

```

        services.registerService(
            serviceName, endpointURI);
    }

    @PreDestroy
    public void unregisterService() {
        services.unregisterService(
            serviceName, endpointURI);
    }
}

```

We use the `@PostConstruct`, `@PreDestroy`, and `@ApplicationScoped` annotations to make sure we register and unregister the service only once per lifecycle. The `BASE_URI` environment variable should contain the microservice's public URI. We can now create a similar bean for each of our microservices.

Injecting the Microservices at the Front End

We can use the just-described approach for injection on the front end to connect to the REST services. We can inject our `ServiceDiscovery` bean to our JSF backing bean to retrieve the URL of a microservice we want to invoke, as shown below:

```
@Model
public class BookingsBean {

    @Inject
    ServiceRegistry services;

    public List getAllBookings() {
        return ClientBuilder.newClient()
            .target(services.discoverServiceURI(
                "trains-booking"))
            .path("bookings")
            .request().get(List.class);
    }
}
```



```
$ docker build -t trains/ui \
    -f ui/Dockerfile .
$ docker build -t trains/routes \
    -f routes/Dockerfile .
$ docker build -t trains/bookings \
    -f bookings/Dockerfile .
```

Once built, these images can be run anywhere Docker or the Docker API is used, as well as anywhere Docker Swarm, Kubernetes, various PaaS providers, and many such services are used. To test the images, we can run them locally. We also need to start a ZooKeeper instance by using an existing image. Don't forget to pass the required environment variables to our microservices (using the `-e` switch). The following example uses `172.17.42.1` as the Docker host, because that is the default. Adjust as needed.

```
$ docker run -p 2181:2181 -d fabric8/zookeeper
$ docker run --name ui -p 3000:8080 -d \
-e BASE_URI='http://172.17.42.1:3000' \
-e ZOOKEEPER_URI=172.17.42.1:2181 trains/ui
$ docker run --name routes -p 3001:8080 -d \
-e BASE_URI='http://172.17.42.1:3001' \
-e ZOOKEEPER_URI=172.17.42.1:2181 trains/routes
$ docker run --name bookings -p 3002:8080 -d \
-e BASE_URI='http://172.17.42.1:3002' \
-e ZOOKEEPER_URI=172.17.42.1:2181 trains/bookings
```

We can now browse our microservice application at `http://localhost:3000` or browse our REST services for the `routes` and `bookings` modules at `http://localhost:3001` and `http://localhost:3002`, respectively.

Conclusion

In this article, we have seen how to develop microservices with standard Java EE using the open source KumuluzEE framework. As demonstrated, the KumuluzEE framework

automates tasks related to the configuration and deployment of microservices. With simple dependency definitions in Maven, it allows us to create self-contained, standalone JAR files, which contain the required execution environment. Therefore, they can be executed within a standard JRE without requiring an application server. This way, microservices with KumuluzEE provide a minimal footprint and are a good fit for executing in cloud, PaaS, and Docker-style environments, which was demonstrated with this [example](#). We also saw how to handle service discovery using ZooKeeper.

KumuluzEE is an enabler for a microservices architecture in Java EE. The major benefit is that it allows us to use standard Java EE APIs to develop microservices. This way we can also port existing applications to microservices. Although at first blush, microservices might look odd to traditional app server developers, many technologists believe microservices represent the future of Java in the cloud. Feel free to download [KumuluzEE](#) and try it out. [</article>](#)

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Getting Started with KumuluzEE

Quiz Yourself

Test questions from the author of the Java certification tests

SIMON ROBERTS

[In order to expand this section and make it more useful, we asked Simon Roberts, an author of many of the certification tests, to develop questions and answers for us. Unlike the contents of previous columns, Simon provides detailed and in-depth explanations of why a given solution is correct. We hope you like this new expanded format. If so or if not, drop me a line. —Ed.]

These questions are intended to be at the same level of difficulty as the 1Z0-809 Programmer II exam, and they should serve at least two purposes. First, I hope that for many readers they might introduce something new, or clarify some subtle aspect of the Java language. Second, of course, I hope they'll give some insight into how exam questions might look, the kind of difficulty they might present, and how you might go about answering them.

Question 1. Given this code:

```
public class Outer {
    private int x = 99;

    private class Inner {
        private int x = 100;

        public void show() {
            System.out.println(x); } // line n1
        public void show0() {
            System.out.println(Outer.this.x); } // line n2
    }

    public void show(Inner i) {
```

```

        System.out.println(i.x); } // line n3
    public void show() {
        System.out.println(x); } // line n4

    public static void main(String [] args) {
        Outer o = new Outer();
        Inner i = o.new Inner(); // line n5
        o.show(); o.show(i);
        i.show(); i.showO();
    }
}

```

Which two, taken individually, are true? Choose two.

- a. At line n2, the expression `Outer.this.x` has the value 99.
- b. `Outer.this.x` at line n2 fails because `x` in the `Outer` class is inaccessible from `Inner`.
- c. The expression `Outer.this.x` at line n2 is a syntax error that should read `super.x`.
- d. The expression `i.x` at line n3 has the value 100.
- e. The access to `i.x` at line n3 fails because `x` in the `Inner` class is inaccessible from `Outer`.

Question 2. Given this interface:

```
public interface Clothing {
    int getSize();
    String getColor();
}
```

What changes must be made to the following class to allow its use as a generic container of clothing items?

```
public class Pair {           // line n1
    private E left, right;    // line n2
```

- Modify the type `E` to be `Object`.
- Modify `line n1` to:

```
public class Pair<? extends Clothing> {
```
- Modify `line n1` to:

```
public class Pair<E super Clothing> {
```
- Modify `line n1` to:

```
public class Pair<E extends Clothing> {
```
- Modify the variable declarations on `line n2` to:

```
private Clothing left, right;
```

Given that the `length()` method returns an `int`, to which two standard functional interfaces can the lambda expression be assigned? Choose two.

- 
- A 3D rendered character with a white body, black limbs, and a large red sphere for a head is shown from the side, holding a silver flagpole. The character is waving a white flag that has the word "Answers" written on it in a bold, black, sans-serif font. The character is standing on a light gray shadow.

In essence, any `private` element is visible anywhere inside the enclosing top-level curly braces that surround it. For simple situations, the two descriptions might be the same, but in the case of nested or inner classes, the `private` elements of inner and outer classes are all visible from both classes. [Section 6.6.1](#) of the *Java Language Specification* notes that “...declared `private`,...access is permitted if and only if it occurs within the body of the top level class...that encloses the declaration....”

Given this, Options A and D are correct. Options B and E, which assert that the `private` fields are essentially accessible only inside their own defining classes, are incorrect.



an enclosing class ([section 15.11.2](#)). Given this, Option C is also incorrect.

Therefore, Options A and D are the only correct answers.

Question 2. The correct answer is Option D. There are two problems with the `Pair` class as it stands. The first is that the generic type variable `E` is not declared. This would require, at a minimum, that the class declaration on `line n1` be modified to look like this:

```
public class Pair<E> {
```

However, if that is the only change made, the underlying type of `E` will be taken as `Object`; that is, there will be no restrictions on what types this `Pair` can be made to contain, other than that the `left` and `right` elements must be the same type. Because of this, the attempts to call the `getSize` and `getColor` methods in the `isMatched` method will fail.

For this class to work properly, we need to ensure that whatever `E` is in any given use of the class, it's something that implements the interface `Clothing`. That way, the basic type of the variables `left` and `right` will be `Clothing`, and the calls to the methods `getSize` and `getColor` will compile successfully.

To make this happen, the syntax of the class declaration is as shown in option D. (The syntax is formally called out in section 8.1.2 of the *Java Language Specification*.)

Section 8.1.2 also makes clear that type bounds of this kind are declared using `extends`, not using `super`. The use of `super` in angle brackets relates to lower-bounded wildcards and is not relevant here. Consequently, option C is incorrect.

Option B also tries to use a syntax that is incorrect in this context, and is more closely related to that of a bounded wildcard. Because `line n1` must declare the generic type variable, it must be declared by name `E` and not by using the `<? ...>` format that is used by bounded wildcards.

Consequently, option B is also incorrect.

Option A is incorrect for two reasons. First, it fails to fulfill the requirement that the `Pair` class be generic. However, more severely perhaps, it still would not permit the class to compile, because the attempt to invoke the `getSize` and `getColor` methods in the method `isMatched` would fail.

Option E also fails to compile. Although it would be possible to create this class in a nongeneric format, making the variables of type `Clothing`, this would also require that the constructor arguments be `Clothing` to allow the code to compile. Because that additional change is not mentioned in option E, the option fails and must be rejected. Further, even if the supporting changes were also made, the class would not be generic, as called for in the question.

Question 3. The correct answers are options A and D. Using lambda expressions, we give the compiler what amounts to “parts of a class definition” and ask the compiler to fill in the blanks from the context. Given a lambda without context, it’s possible to view the lambda in different ways, and the blanks might be filled in very differently.

In this example, we know that the return type of the lambda is `int`, because that's the type of the `length` expression. So whatever we hope to make from this must return an `int` or, via autoboxing, an `Integer`.

Any of the listed functional interfaces could satisfy this requirement, so to move forward, we must consider what we know about the argument types of the lambda.

One thing we know is that there is a single argument, called `s`. That means that the `IntSupplier` is not compatible with this lambda expression, because `IntSupplier` (like all `Supplier` interfaces) takes zero arguments. So, we can rule out option C.

We also know that the argument type is some kind of object, not a primitive. We know this because we are able to invoke this mysterious `length()` method on the argument `s`. (Note

```
//fix this /
```

that it's tempting to assume that this argument is a `String`, but we neither know that nor need to know that.) Let's consider the remaining options in light of this, and assume that the type of the argument `s` is defined by some imaginary interface `HasLength`.

The argument and return types of a function are defined independently, so a `Function<HasLength, Integer>` would match our lambda successfully, and option A is a correct answer.

The argument type of an `IntFunction` is a primitive `int`; therefore, option B can be ruled out.

We already eliminated option C, so we'll ignore it now.

The `ToIntFunction` takes an argument of a generic type and returns a primitive `int`, so `ToIntFunction<HasLength>` fits our lambda perfectly, too. It's worth noting that this is in a sense the “best fit” because it avoids the autoboxing of the return value, but the question doesn't get into such value judgments. But clearly option D is correct, too.

The argument type and return type for a `UnaryOperator` are constrained to be the same. We already know the return is `int`, so the only way that `UnaryOperator` might possibly match our lambda is as `UnaryOperator<Integer>`. That would work only if the `Integer` object has a `length()` method. Of course, it doesn't, so option E cannot work either. **</article>**

Simon Roberts joined Sun Microsystems in time to teach Sun's first Java classes in the UK. He created the Sun Certified Java Programmer and Sun Certified Java Developer exams. He wrote several Java certification guides and is currently a freelance educator who teaches at many large companies in Silicon Valley and around the world. He remains involved with Oracle's Java certification projects.

