LINUX AND REAL-TIME JAVA FOR IOT

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EMBEDDED SYSTEMS EVOLUTION

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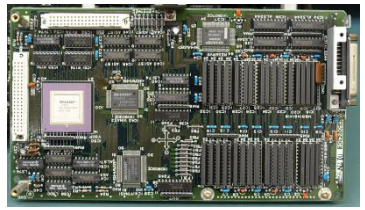
'80s	'90s	'00s	'10s



Hardware:

- CPU, Mem, Peripherals
- Custom board
- $$ Manufacturing

→

- Chipsets
- Std. Interfaces
- Std. Form Factors
- Commercial Boards

→

- Multicore SoCs
- On-chip Interfaces
- Stacked DRAM, Flash
- MEMS Sensors
- Open Source Boards

Software:

- RYO kernel/exec
- Custom drivers
- Assembly Code

→

- Commercial RTOS
- Customized BSP
- C, Assembly

→

- Embedded Linux
- Open Source Drivers, Libs
- C++, Java, Python, Javascript…

TECHNOLOGY CONVERGENCE TO THE IOT

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Embedded Systems

SoCs, MEMS, Open Source h/w, C++, Java, Embedded Linux

Cloud Computing

Virtualization, Containers, IaaS/PaaS/SaaS, SDN, NFV, OpenStack

Big Data, Deep Learning

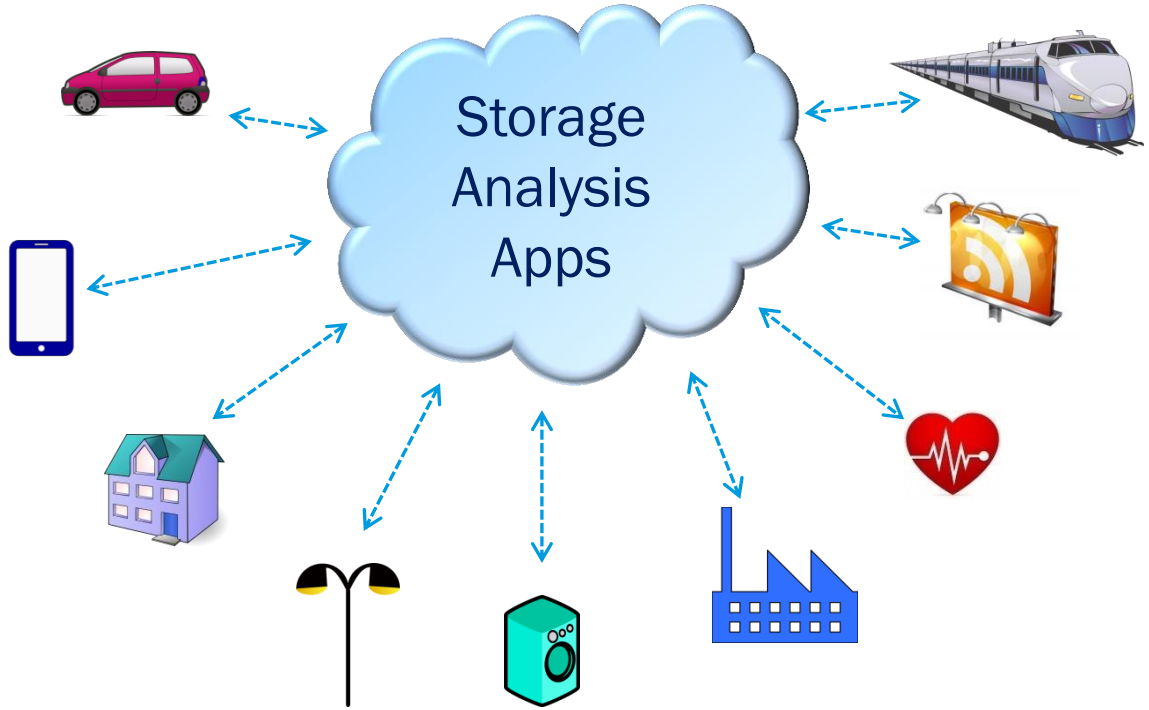
Hadoop, MongoDB, Spark, TensorFlow, Torch, Leaf, Caffe

Wireless Connectivity

LTE, WiFi, Bluetooth LE, ZigBee, 6LoWPAN, LoRa, Sigfox, Weightless

Smart, Connected Products:

- Transportation
- Energy
- Health Care
- Agriculture
- Retail
- Industrial Control
- Home/Building Automation
- Smart Cities
- …and many more…



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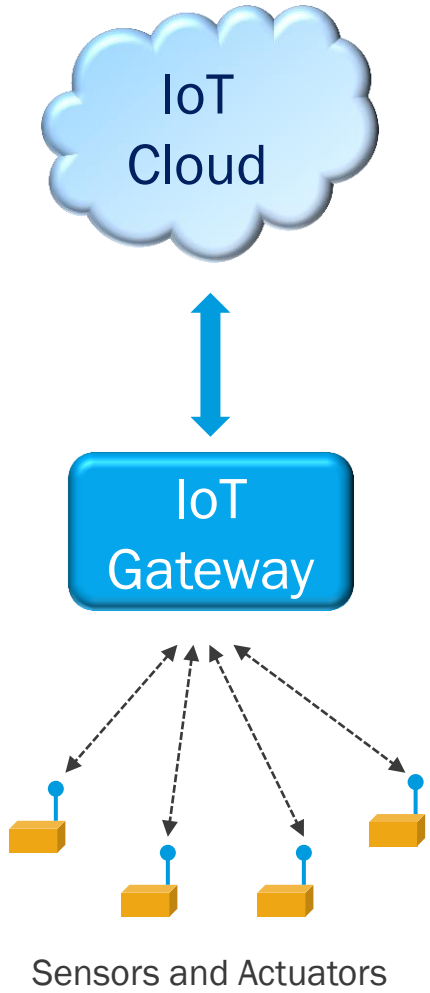
An IoT Gateway:

- Acts as a communications access point between networks
- Provides intelligence and storage at the Edge of the network
- Aggregates, filters, validates data from low-level sensors, forwarding results to the Cloud
- Controls actuators on behalf of Cloud commands and in response to local events



BENEFITS OF IOT GATEWAYS

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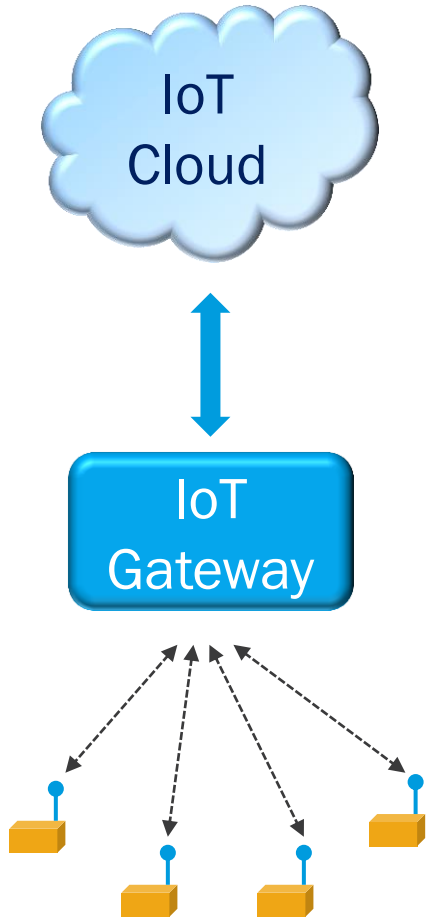
IoT Gateways can:

- Connect legacy devices to the Internet of Things
- Assure secure communications with the Cloud
- Provide separation and isolation of end-nodes
- Be easily updated, adapted, configured over the network
- Relieve processing and storage demands from end-nodes
- Reduce overall costs while scaling up
- Help diagnose and troubleshoot device failures
- Offer local autonomy and intelligence
- Respond quickly to time-critical events



Sensors and Actuators

THE IOT GATEWAY SOFTWARE STACK

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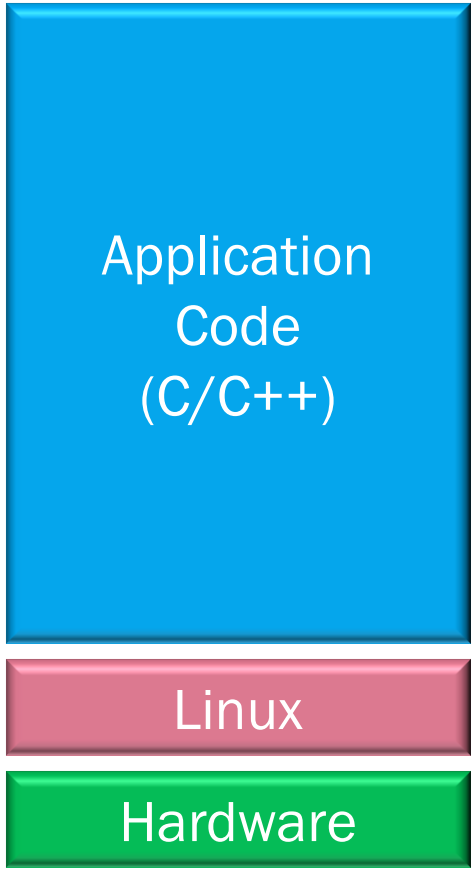
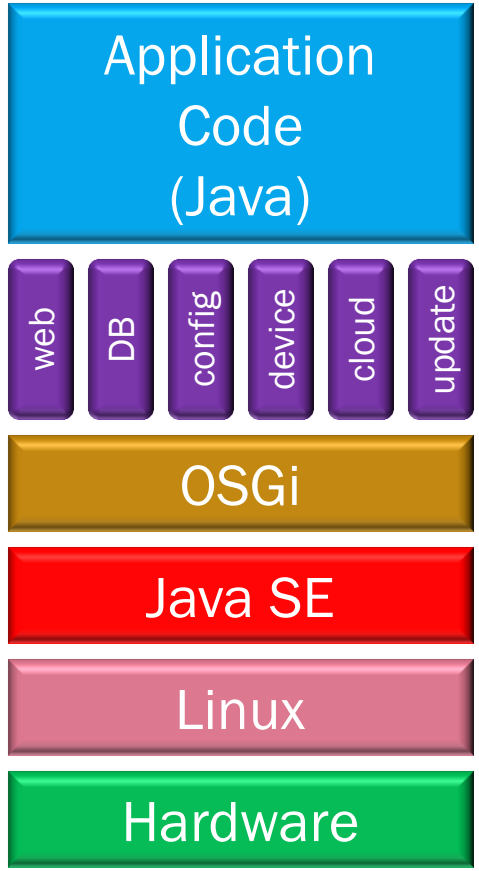
Developers can:

Build it from scratch…



Use a high-level language for faster development…

Or leverage frameworks and services…



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Java Brings these Great Features:

- ✓ High-level object-oriented programming
- ✓ Automatic garbage collection
- ✓ Robust Security and Exception handling
- ✓ Built-in threading model
- ✓ Dynamic loading, unloading, re-loading of code without reboot
- ✓ Platform independence
- ✓ Excellent support for networking, concurrency, database, collections, plus thousands of 3rd party libraries

Java

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Open Systems Gateway initiative (OSGi):

- A framework for developing, deploying, and managing software components written in Java.
- Components called bundles hide internals and communicate through well-defined services.
- Bundles register, get, and listen to services in a registry. They can adapt their function based on available services.
- Dependencies and versioning among bundles are managed automatically.
- Bundles can be installed, started, stopped, updated, and uninstalled without bringing down the system.

OSGi

OSGI FOR IOT RESOURCES

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Apache Felix http://felix.apache.org/

Full-featured OSGi framework with many useful services.

Eclipse Kura http://www.eclipse.org/kura/

Contributed by Eurotech. Includes services for I/O, Messaging (MQTT, CoAP), Networking (WiFi, Ethernet, Cellular), Watchdog, Web UI. Uses Eclipse Equinox OSGi framework.

Eclipse Concierge http://projects.eclipse.org/projects/rt.concierge

From Ghent University. Small-footprint OSGi framework (~300K). Runs Kura and Felix services.

ProSyst Bosch Group mBS http://www.prosyst.com/startseite/

Commercially supported OSGi framework for IoT.

OSGi homepage https://www.osgi.org/

OSGi

WHAT ABOUT REAL TIME?

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Consider:

Elevator Call Button

vs.

Automobile Brake Pedal

A Real-Time System:

- Must Process information and guarantee a response within a specified time.
- Missing the deadline (even if the response is correct) is a failure; and if safety critical, may result in loss of life or limb.
- Real Time is as much about predictability as speed.

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When is Real Time Required?
When Milliseconds Matter!

If your brakes engage in 10 milliseconds nine times out of ten but then once after 2 seconds, is the average of 209 ms acceptable?

Real-World, Real-Time Examples:

- ❑ **Factory Automation** - Machine tool on a factory floor
- ❑ **Logistics** - Automated airport baggage sorter
- ❑ **Driver Assistance** – Driver fatigue detection
- ❑ **Energy** - Wind turbine gearbox
- ❑ **Building Automation** – HVAC fire response
- ❑ **Public Access** - Stadium entrance gates

TRADITIONAL JAVA PROBLEMS

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Why Traditional Java can't do Real Time:

- ❑ Garbage Collector Pauses
- ❑ JIT Compiler Interference
- ❑ Page Fault Delays
- ❑ Lack of Precise Timing Control
- ❑ Limited Thread Scheduling Control
- ❑ Priority Inversions

~~Traditional Java~~

WHAT ARE MY CHOICES?

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Alternatives to Traditional Java for Real Time:

- Go back to C or C++
- Split the application into RT/non-RT
- Try tuning the GC and hope for the best
- Try a “pauseless” GC implementation
- Try an RTSJ implementation
- Use a Real-Time Java SE

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Look for these Features in a Real-Time Java:

- ✓ Garbage Collector (GC) can be preempted at any time by high priority threads and then resume collecting.
- ✓ Ahead-of-Time compilation and early JIT available.
- ✓ Can lock memory pages into physical RAM.
- ✓ Provides jitter-free timing APIs for critical tasks.
- ✓ GC and Java threads are prioritized and strictly scheduled. JVM provides user control over scheduler timing. Can use real-time policies for hard-prioritized Linux scheduling.
- ✓ Implements Priority Inheritance Protocol to avoid inversions.

Real-Time Java SE

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Real-Time Linux Options:

- Get a commercial RT Distribution
- Apply kernel Preempt-RT patches
- Set kernel CONFIG_PREEMPT, CONFIG_HIGH_RES_TIMERS

Tips and Tricks:

- Disable CFS Bandwidth Enforcement
- Boost ksoftirqd thread policy/priority
- Use SCHED_RR or SCHED_FIFO policy
- Call mlockall()
- Pre-allocate memory

Real-Time Linux

DEMONSTRATION OF REAL-TIME JAVA

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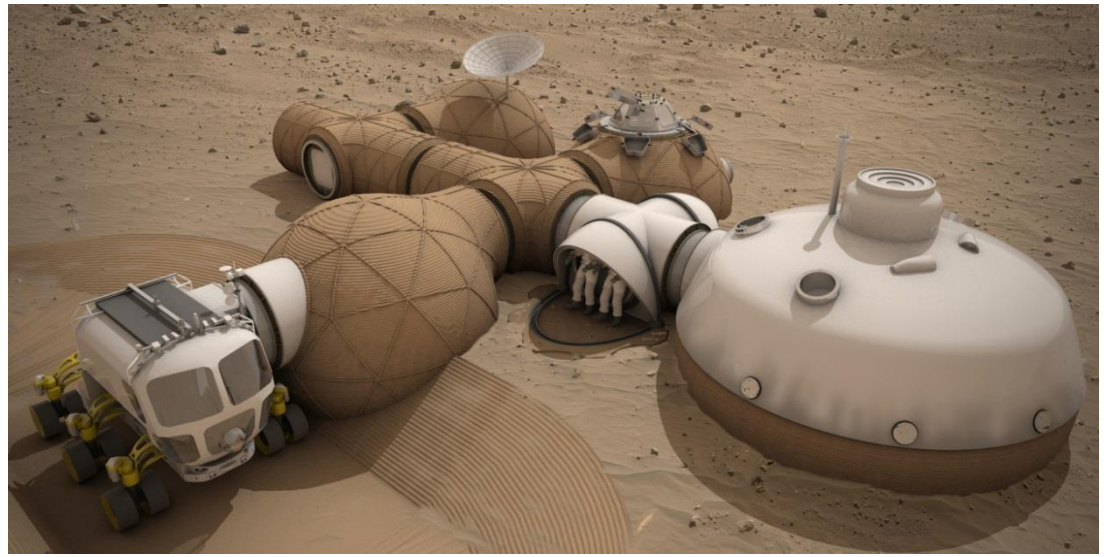
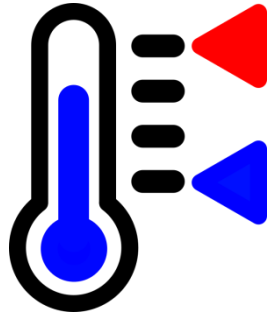


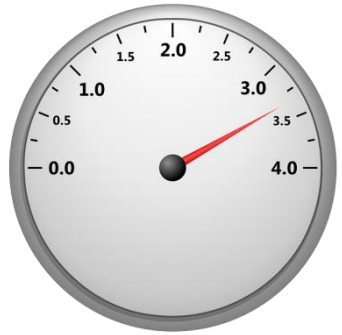
http://www.nasa.gov/sites/default/files/thumbnails/image/lavahive.jpg

Problem Statement:

- You are an astronaut stranded on Mars.
- You need to grow enough food to survive until a rescue mission arrives.
- You build a greenhouse inside your habitat to grow potatoes.
- You need an IoT Gateway to automate the greenhouse.

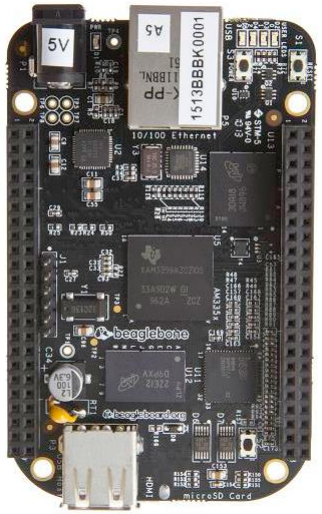
http://mattermasters.wikispaces.com/Classification+of+Plants

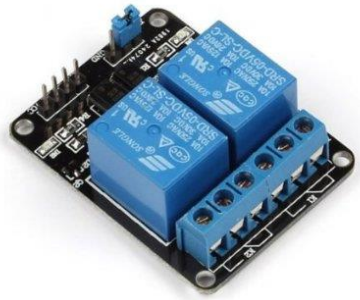




Mars Greenhouse IoT Gateway Requirements:

- Monitor and display sensor data for available sunlight, internal temperature, and pressure.
- Store sensor data and transmit to the IoT Cloud at Mission Control.
- Round-trip delay for communication with Earth requires local control of internal lights and heat to adapt to changing conditions (i.e. dust storms).
- Bonus: Track harvested potatoes, estimated astronaut TTS (Time to Starvation).





Mars Greenhouse IoT Gateway Hardware:

- BeagleBone Black Rev. C, 1 GHz ARM Cortex-A8, 512 MB DDR3 RAM, 4GB on-board Flash, I2C, AIN, GPIO, Ethernet, USB
- CdS Photoresistor
- BMP085 I2C Temperature/Pressure Sensor
- LEDs, Relays

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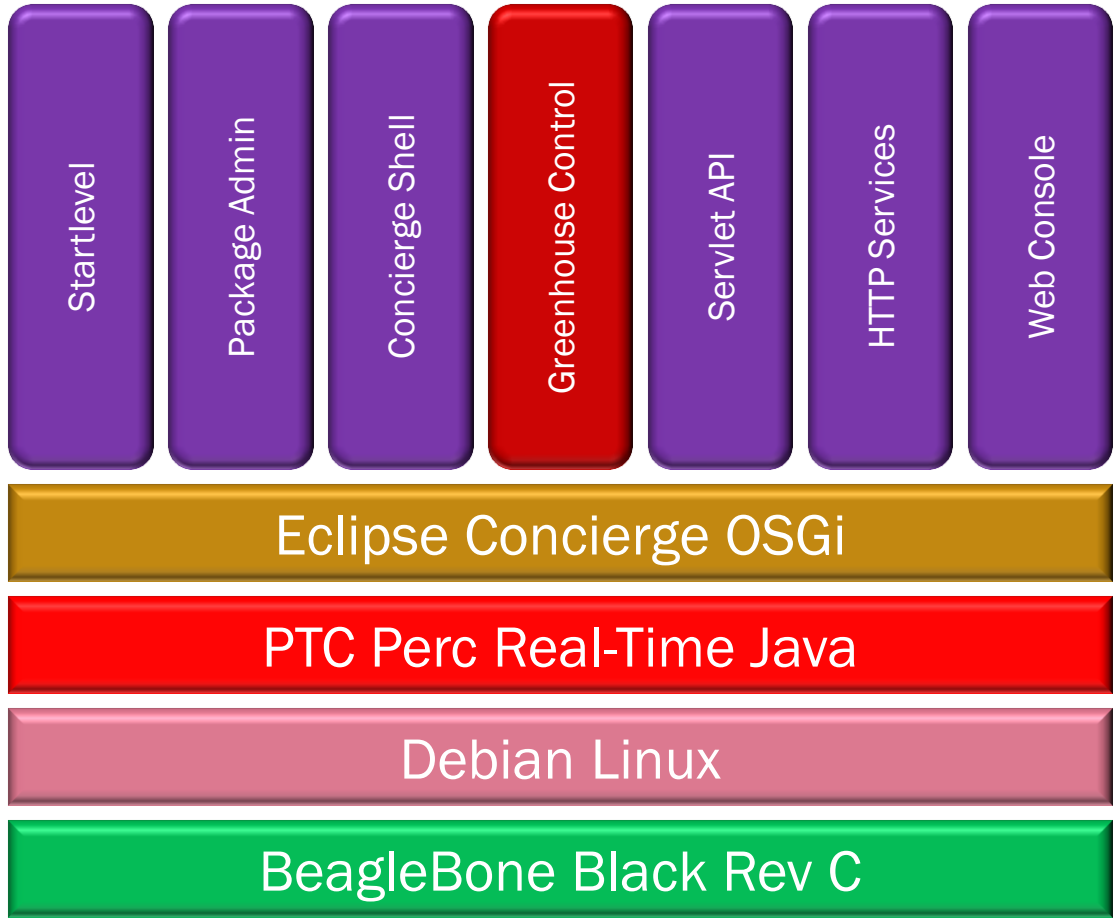
Mars Greenhouse Software Stack:



DEMONSTRATION OF REAL-TIME JAVA

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BBB.java

```
public void run()
{
  float lthresh = 0.5f;
  float tthresh = 21.1f;
  Thread.currentThread().setPriority(10);
  System.loadLibrary("mars_BBB");
  try
  {
    lthresh = Float.parseFloat(System.getProperty("light_thresh", "0.5"));
    tthresh = Float.parseFloat(System.getProperty("temp_thresh", "21.1"));
  }
  catch (NumberFormatException nfe)
  {
  }

  initBBBNative();
  running = true;
  while(running)
  {
    light = getBBBLight();
    boolean old_lights = lights_on;
    lights_on = (light < lthresh) ? true : false;
    if (old_lights != lights_on)
    {
      setBBBYellow(lights_on);
    }

    doBBBSample();

    temp = getBBBTemp();
    boolean old_heat = heat_on;
    heat_on = (temp < tthresh) ? true : false;
    if (old_heat != heat_on)
    {
      setBBBRed(heat_on);
    }

    kpa = getBBBKpa();
    updateSim();
    try
    {
      Thread.sleep(100);
    }
    catch (InterruptedException ie)
    {
    }
  }
  closeBBBNative();
  done = true;
}
```

DEMONSTRATION OF REAL-TIME JAVA

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Mars.java

```java
public void doGet(HttpServletRequest request,
                  HttpServletResponse response)
          throws ServletException, IOException
{
  if (request.getParameter("reset") != null)
  {
    bbb.resetSim();
  }
  // Set refresh, autoload time as 1 seconds
  response.setIntHeader("Refresh", 1);

  // Set response content type
  response.setContentType("text/html");
  PrintWriter out = response.getWriter();
  float light = bbb.getLight() * 100.0f;
  float temp = bbb.getTemp();
  float kpa = bbb.getKpa();

  boolean lights_on = bbb.getLightsOn();
  boolean heat_on = bbb.getHeatOn();

  int elapsed = bbb.getElapsed();
  int plants = bbb.getPlants();
  int harvest_count = bbb.getHarvestCount();
  int harvested = bbb.getHarvested();
  int re_seeded = bbb.getReSeeded();
  float consumed = bbb.getConsumed();
  float available = bbb.getAvailable();
  float tts = bbb.getTTS();


  String lightval = String.format("%.1f", light);
  String lightpct = String.format("%d", (int)light);
  String tempval = String.format("%.1f", temp);
  int tpct = (int)((temp + 20.0f) * (100.0f / 80.0f));
  if (tpct < 0) tpct = 0;
  if (tpct > 100) tpct = 100;
  String temppct = String.format("%d", tpct);
  String kpaval = String.format("%.1f", kpa);
  int kpct = (int)(kpa * (100.0f / 120.0f));
  if (kpct < 0) kpct = 0;
  if (kpct > 100) kpct = 100;
  String kpapct = String.format("%d", kpct);

  String lights_on_active = lights_on ? " on-active" : "";
  String lights_off_active = lights_on ? "" : " off-active";
  String heat_on_active = heat_on ? " on-active" : "";
  String heat_off_active = heat_on ? "" : " off-active";
```


```java
  String lightval = String.format("%.1f", light);
  String lightpct = String.format("%d", (int)light);
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```
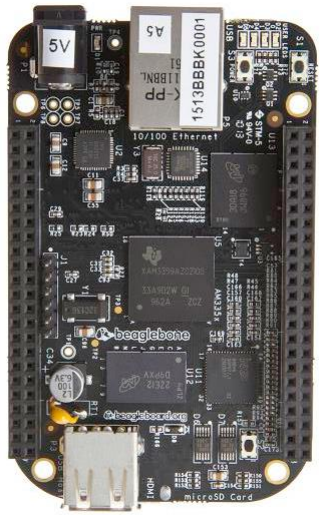


```java
  String elapsedval = String.format("%d", elapsed);
  String plantsval = String.format("%d", plants);
  String harvestcntval = String.format("%d", harvest_count);
  String harvestedval = String.format("%d", harvested);
  String re_seededval = String.format("%d", re_seeded);
  String consumedval = String.format("%.1f", consumed);
  String availableval = String.format("%.1f", available);
  String ttsval = String.format("%.1f", tts);

  String newhtml = String.format(prehtml, lightval, lightpct, tempval,
                                 temppct, kpaval, kpapct,
                                 lights_on_active,
                                 lights_off_active,
                                 heat_on_active,
                                 heat_off_active,
                                 elapsedval, plantsval,
                                 harvestcntval, harvestedval, re_seededval,
                                 consumedval, availableval, ttsval);
  out.println(newhtml);
}

// Method to handle POST method request.
public void doPost(HttpServletRequest request,
                   HttpServletResponse response)
    throws ServletException, IOException
{
   doGet(request, response);
}
```

DEMONSTRATION OF REAL-TIME JAVA



Demo Time!

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In Conclusion:

- Gateways are an important element in building scalable IoT systems.
- Java provides a great foundation for developing IoT Gateways.
- OSGi adds a robust software component model to Java.
- When a gateway or any other embedded system needs to respond quickly and predictably to events, a true Real-Time Java solution is your best choice.

Real-Time Java SE

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Q&A

For more information, please visit:

- PTC Perc Real-Time Java:

  http://www.ptc.com/developer-tools/perc