Automated Performance Modeling for IoT Systems

Connie U. Smith & Amy Spellmann
Performance Analysis for Internet of Things – Topics for Today

- Introduction to IoT performance
- Why it’s important for our focus as performance specialists
- Case Study: IoT Surveillance Camera analysis
- Status: Research & Automation
Internet of Things

- Millions of data streams
- Complex architectures
- Disruptive technologies
- Performance matters!
Poor IoT Performance is Noticeable
Responsiveness has Competitive Edge

Best time-saving appliances and electronics
Consider these top-performing products for your home
Published: January 2015
Why should we as performance analysts care about IoT?

- 60% of Enterprises are implementing in-house IoT systems for highly visible, strategic initiatives.
- Enterprise development teams have little to no experience designing IoT systems.
- You can be the hero by preventing performance problems before deployment.

Save costs, avoid failures & deliver products faster.
App Connects to Device
Must deal with data import, processing, storage, & analysis of hundreds of millions of events or images per hour.

Data storage & analytics, Edge vs. Core processing

Where should encryption be performed?

Sample IoT Real-time Stream Processing Architecture

Case Study: Surveillance Camera Analysis
Case Study Goals

- Evaluate the performance of the IoT design to provide predictive analytics for 2700 surveillance cameras, 1900 (1kb) msgs/sec (equates to 1 Megapixel/sec)
  - Based on an IoT distributed stream processing benchmark with predictive analytics* and open-source AES (Advanced Encryption Standard) software
- Obtain predictive analytics from image data in a timely manner
- Determine the best design to meet requirements for performance & cost

** RIoTBench: A Real-time IoT Benchmark for Distributed Stream Processing Platforms; Anshu Shukla, Shilpa Chaturvedi and Yogesh Simmhan, Department of Computational and Data Sciences, Indian Institute of Science

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IoT Surveillance System Performance Questions

- Where should encryption/decryption be done? Camera vs. on-prem?
- Where should filtering be done? Camera vs. on-prem?
- How many servers are needed to process 1 megapixel/sec? Expected latency?
- What is the performance effect of architecture & design alternatives?
IoT Surveillance Camera System – Basic Camera

How should we architect the system? Will a basic camera work or is a smart camera necessary?

2700 Basic Cameras

Data stream

Images

Encrypt
Filter
Predictive Analytics

Lookup related
Results

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Baseline – Basic Camera Scenario

- **Camera**: Capture
- **AES**: AESencryptimage(megapixels 1028)
- **Filter**: Filter
- **Analytics**: Predictive Analytics
- **Azure Table**: tableInsert, tableLookup, tableLookupResults, tableInsertResults

- **Raw Image (megapixels 1028)**: 9.6 ms
- **AES Encrypt Image (megapixels 1028)**: 0.21 ms
- **Decrypted Results**: 9.6 ms
- **AES Decrypt**: 0.32 ms
- **AES Encrypt Results (megapixels 3000)**: 9.6 ms
- **Table Insert**: 60 ms
- **Table Lookup**: 0.21 ms
- **Table Lookup Results**: 9.6 ms

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Methodology/Results for Basic Camera

- Evaluate processing requirements for 1 megapixel/sec for the Basic Camera or 1900kb/sec

- Total service time without contention is .07 seconds per kb

- 10 Cores per server; add servers until reasonable residence time is achieved (10 core increments)
  - Processing times are derived from the RIoT benchmark & our own AES encryption performance tests

<table>
<thead>
<tr>
<th>Residence Time/kb</th>
<th>Utilization</th>
<th>#CPUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>2927</td>
<td>100%</td>
<td>50</td>
</tr>
<tr>
<td>0.205</td>
<td>80%</td>
<td>70</td>
</tr>
<tr>
<td>0.159</td>
<td>70%</td>
<td>80</td>
</tr>
</tbody>
</table>
Expensive smart cameras that perform encryption, filtering are powerful but are they worth it? $1000 apiece

2700 Smart Cameras

Encrypt
Filter

Data stream

Images
Lookup related
Results

Predictive Analytics
Methodology/Modeling Results Smart Camera

- Message arrival rate is reduced since the smart camera sends only frames that are already filtered, encrypted
- Processing steps reduced to reflect sequence diagram

<table>
<thead>
<tr>
<th>Residence Time (sec/kb)</th>
<th>Utilization</th>
<th>#CPUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.106</td>
<td>56%</td>
<td>20</td>
</tr>
<tr>
<td>0.085</td>
<td>14%</td>
<td>80</td>
</tr>
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OR Optimize AES algorithms for the Basic Camera

- Refine the AES Algorithm to reduce processing time
  - Potential to achieve a 60% improvement

- Rerun Basic Camera Scenario

<table>
<thead>
<tr>
<th>Residence Time (sec/kb)</th>
<th>Utilization</th>
<th># CPUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.107</td>
<td>74%</td>
<td>30</td>
</tr>
<tr>
<td>0.083</td>
<td>44%</td>
<td>50</td>
</tr>
<tr>
<td>0.078</td>
<td>28%</td>
<td>80</td>
</tr>
</tbody>
</table>

**With AES Tuning**

**Original Basic Camera Results**
Comparison

- Neither design accomplishes real-time streaming, as the Azure table lookup limits residence time per kb (60ms) - better design would make the Azure table lookup asynchronous.
- For this initial analysis, smart cameras provide the best residence time with 50 CPUs/5 servers but Basic cameras with 5 servers can achieve similar IF the AES algorithm is improved.

Comparison of Scenarios: CPUs & Residence Time

<table>
<thead>
<tr>
<th>Scenario</th>
<th>CPUs</th>
<th>Residence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Camera</td>
<td>80</td>
<td>0.159</td>
</tr>
<tr>
<td>Smart Camera</td>
<td>50</td>
<td>0.087</td>
</tr>
<tr>
<td>Basic Tunded AES</td>
<td>50</td>
<td>0.083</td>
</tr>
</tbody>
</table>

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Don’t run out & spend $2.7M on smart cameras!

There are other options to evaluate from a cost & performance perspective

1. Asynchronous Azure lookup
2. Pipeline architecture
3. Lower resolution
4. Buffering frames
5. Fewer/different cameras
6. Azure vs. on-prem storage
7. In a disaster, there would be much more surveillance data

☐ This analysis is representative of how to apply SPE to IoT
☐ We are illustrating how to do the analysis
☐ Adapt it to your situation

More to come

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Status
Software Performance Engineering (SPE) Goal

- Early, model-based assessment of software decisions to determine performance impact
- Architecture
  - Has the most significant influence on performance
  - Most difficult to change
SPE-ED+ Significance

- IoT Systems Disruptive Technology:
  - New developer challenges: UI design, networks, interface to backend systems
  - Time disparity - UI in seconds, controls in ms.
  - Lean RTOS -> Multiprocessing OS eg. Windows Embedded
  - Security issues

- Performance problems are unexpected, visible and newsworthy

- Lack of performance management tools
Vision: Developers Do Robust Engineering

- We cannot continue to build systems with yesterday's methods
- Automated assessment of software and systems architecture is essential
Automated Modeling for Performance (AMP)

- Models automatically generated from design specs in a variety of formats
- Results that developers can use to explore options quickly and easily
- Model interchange formats enable plug and play model solutions
R&D: SPE·ED -> RTES/Analyzer -> SPE·ED+

- SPE·ED - L&S Product
  - Users are performance experts
  - Solid modeling foundation for new products

- AMP- Automated Models for Performance
  - Target developers as users
  - Real-Time & Embedded System modeling extensions
Status

- RTES/Analyzer architecture and enabling technology are positioned for future development
- SBIR Phase 2 funding x 2
- Completing prototype RTES/Analyzer to demonstrate the viability for developers
- Seeking additional comprehensive case study data
- Seeking partners for Phase 3
Summary

- IoT systems are increasingly being developed by enterprises & technology providers.
- We as performance analysts can facilitate the development of IoT systems that perform the first time.
- We demonstrated how SPE can be applied to an IoT system with modeling in the design stage & how designs can relate to overall system costs.
- Additionally, we can assist developers in preventing performance problems in their new systems.
Questions?

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