IOT & Big Data Systems:
Technologies, Challenges and Opportunities

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About Me

- Professor of Computer Science and Director of MSc Program in Health Informatics Department at King Saud bin Abdulaziz University for Health Sciences (KSAU-HS) since 2014.

- Before joining KSAU-HS, held appointments in several academic and research institutes including UNSW, DATA61/CSIRO (formerly NICTA), Macquarie University, Microsoft Research and Nokia Bell Labs.

- Served as a visiting professor in several institutes: Technical University of Dresden, Humboldt University of Berlin and University of Zurich.

- Published more than 100 refereed research publications in reputable international journals and conferences.

- Author/Co-author of 5 books and Co-editor of 3 other books.

- In 2013, awarded the Stanford Innovation and Entrepreneurship Certificate.

- In 2016, winner of the King Abdullah International Medical Research Center (KAIMRC) Best Researcher Award.

- Editor-in-Chief of The Encyclopedia of Big Data Technologies.

- For more information, please visit http://www.cse.unsw.edu.au/~ssakr/
Internet of Things (IoT)

- A network devices, connect directly with each other to capture, share and monitor vital data automatically through a SSL that connects a central command and control server in the cloud
- Enabling communication between devices, people & processes to exchange useful information & knowledge that create value for humans
- A global Network Infrastructure linking Physical & Virtual Objects
  - Infrastructure: Internet and Network developments
  - Specific object identification, sensor, and connection capability
Internet of Things (IoT)

Consumer & Home
Smart Infrastructure
Security & Surveillance
Healthcare
Transportation
Retail
Industrial
Others
Prediction of IoT Usage\(^1\)

Connected devices (billions)

<table>
<thead>
<tr>
<th>Year</th>
<th>Cellular IoT</th>
<th>Non-cellular IoT</th>
<th>PC/laptop/tablet</th>
<th>Mobile phones</th>
<th>Fixed phones</th>
<th>CAGR 2015–2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>0.4 billion</td>
<td>4.2 billion</td>
<td>1.7 billion</td>
<td>7.1 billion</td>
<td>1.3 billion</td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>1.5 billion</td>
<td>14.2 billion</td>
<td>1.8 billion</td>
<td>8.6 billion</td>
<td>1.4 billion</td>
<td>27%</td>
</tr>
<tr>
<td>2021</td>
<td>28 billion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>22%</td>
</tr>
</tbody>
</table>

\(^1\)https://www.ericsson.com/

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Is IoT New?

We’ve doing this for many years

Yes

This is really very fascinating and looks like IoT will change the world
Why IoT opportunity is occurring now?

- **Affordable hardware**: Costs of actuators & sensors have been cut in half over last 10 years
- **Smaller, more powerful hardware**: Form factors of hardware have shrunk to millimeter or even nanometer levels
- **Ubiquitous & cheap mobility**: Cost for mobile devices, bandwidth and data processing has declined over last 10 years
- **Availability of supporting tools**: Big data tools & cloud based infrastructure have become widely available
Data Generation and Consumption Model is Changing
Data Generation and Consumption Model is Changing

- **Old Model**: Few companies (producers) are generating data, all others are consuming data

- **New Model**: All of us are generating data, and all of us are consuming data
IOT for Healthcare

- Blood sampling sensors
- External sensors that connect to the body
- Telemedicine
- Ingestible sensors (for example, in the form of a pill and eventually dissolved)
- Tissue-embedded sensors (for example, a pacemaker or implantable cardio defibrillator)
IOT for Healthcare

Connected Medical Devices

R&D
- Develop better products, faster, informed by a much larger data set based on patient outcomes

Manufacturing
- Manage equipment remotely, using appropriate KPIs
- Reduce machine downtime with condition-based maintenance alerts

Distribution
- Enable advanced product tracking and authentication to prevent counterfeits

Customer Service
- Anticipate medical device maintenance needs, and alert patients to schedule a doctor visit for replacement or repair

Healthcare Provider
- Monitor medical device functionality for better customer service, reduced risk, and insight to improve product design
- Monitor device data to make more timely health decisions, such as adjusting dosages

Patient Home
- Aggregate and correlate data from disparate medical devices with medications and health outcomes for advanced insight
IOT for Smart Cities

Smart City Components

- Smart government
- Mobility/Wi-Fi
- Smart manufacturing
- Open data
- Smart/ digital citizens
- Smart health
- Smart farming/ agriculture
- Smart buildings
- Smart grid/ energy/ utilities
- Smart transportation

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IOT for Industry 4.0

Industry 4.0

Internet of Things

Robotics

Industry 3.0

Industry 2.0

Industry 1.0

Water, Steam and Mechanical production

Electronics, IT and Automation

Electricity and mass production

Today

20 mill Years ago

Year Zero

~1784

~1870

~1969

~2011->

First mankind

First mankind
What it all produce?

Data ... Data ... Data
Big Data & IOT

BIG DATA & INTERNET of THINGS
Big Data (3V)

**Volume**
Data at Scale
Terabytes to Petabytes of data.

**Variety**
Data in Many Forms
Structured, Unstructured, Text, Multimedia.

**Velocity**
Data in Motion
Analysis of streaming data to enable decisions within fractions of a second.
Big Data & IOT & Analytics

How can we make it happen?

What will happen?

Predictive Analytics

Why did it happen?

Diagnostic Analytics

What happened?

Descriptive Analytics
Big Stream Processing
Big Stream Processing Systems
## Big Stream Processing Systems

<table>
<thead>
<tr>
<th>Streaming Model</th>
<th>Native</th>
<th>Micro-batching</th>
<th>Micro-batching</th>
<th>Native</th>
<th>Native</th>
</tr>
</thead>
<tbody>
<tr>
<td>API</td>
<td>Compositional</td>
<td>Declarative</td>
<td>Compositional</td>
<td>Declarative</td>
<td></td>
</tr>
<tr>
<td>Guarantees</td>
<td>At-least-once</td>
<td>Exactly-once</td>
<td>At-least-once</td>
<td>Exactly-once</td>
<td></td>
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<tr>
<td>Fault Tolerance</td>
<td>Record ACKs</td>
<td>RDD based Checkpointing</td>
<td>Log-based</td>
<td>Checkpointing</td>
<td></td>
</tr>
<tr>
<td>State Management</td>
<td>Not build-in</td>
<td>Dedicated Operators</td>
<td>Dedicated DStream</td>
<td>Stateful Operators</td>
<td>Stateful Operators</td>
</tr>
<tr>
<td>Latency</td>
<td>Very Low</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Throughput</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Maturity</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>
Fog Computing
Fog Computing

- Cloud to Fog
- Fog to Cloud
- Fog to Fog

- Real-time Response
- End Devices

Save Bandwidth

Fog

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Conclusions

**Big Data is the New Oil**

and

**Big Data Processing Systems is the Machinery**
Conclusions

- IoT is one the growing killer applications for big data analytics
- Scalable Big Data processing for IoT platforms involves various unique challenges
- In the last few years, several big stream processing systems have been introduced with various design decisions
- There is still big room for innovations and improvement in several directions including: architecture, applications and systems
Conclusions
Our Handbook on Big Data

Sherif Sakr and Albert Zomaya. "Encyclopedia of Big Data Technologies", Springer, 2018
The End

Thank You
Kiitos
Grazie
Obrigado
Takk
Gracias
Mahalo
Toda
Thanks
Merci