Overview of the Internet of Things (IoT)
Ice-breaking
Course Info

• Instructor: Qian Zhang
  • www.cs.ust.hk/~qianzh

• Course web site
  contains all notes, announcements, etc. Check it regularly!

• Lecture schedule
  • Friday 18:30-21:20 Rm 1504
Course Info

• The reading materials online for paper reading and student presentation
• Check recent research papers from high quality conferences and transactions
• Experience networking research through team projects (1-2 students)
  • Understand what is good research
  • Hands-on experience in IoT related research
  • Appreciate team work / collaborations
Course Info

• Grading scheme
  • Homework  20 points
  • Project    25 points
  • Presentation  15 points
  • Final Exam   40 points

• Paper presentation
  • Everyone reviews and presents 1 paper
  • Email me ids of 3 papers that you’d like to present by Feb. 28
  • Submit a review for one paper of your choice before you present the paper (1 page)
Course Schedule

- Introduction of the Internet of Things (IoT) (1 week)
- RFID: technology and applications (2 weeks)
- Wireless and mobile communications (4 weeks)
- Sensors and wireless sensor networks (3 weeks)
- Localization technologies (1 week)
- Student presentation (2 weeks)
Outline

1. What’s Internet of Things (IoT)
2. State of the Art of IoT
3. Challenges and Limitation of IoT
4. Future of IoT
Starting from the Internet

- Internet appears everywhere in the world
- but it is still a connection between people and people
What is the Internet of Things?

• Internet connects all people, so it is called “the Internet of People”

• IoT connects all things, so it is called “the Internet of Things”
What’s the Internet of Things

- **Definition**

  (1) The Internet of Things, also called The Internet of Objects, refers to a wireless network between objects, usually the network will be wireless and self-configuring, such as household appliances.

    ------Wikipedia

  (2) By embedding short-range mobile transceivers into a wide array of additional gadgets and everyday items, enabling new forms of communication between people and things, and between things themselves.

    ------WSIS 2005
What’s the Internet of Things

- Definition

(3) The term "Internet of Things" has come to describe a number of technologies and research disciplines that enable the Internet to reach out into the real world of physical objects.

--------IoT 2008

(4) “Things having identities and virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate within social, environmental, and user contexts”.

--------IoT in 2020
What’s the Internet of Things

• History
  - 1997, “The Internet of Things” is the seventh in the series of ITU Internet Reports originally launched in 1997 under the title “Challenges to the Network”.
  - 1999, Auto-ID Center founded in MIT
  - 2003, EPC Global founded in MIT
  - 2005, Four important technologies of the internet of things was proposed in WSIS conference.
  - 2008, First international conference of internet of things: The IOT 2008 was held at Zurich.
What’s the Internet of Things

From any time, any place connectivity for anyone, we will now have connectivity for anything!

Figure 1 – A new dimension

Source: ITU adapted from Nomura Research Institute
What’s the Internet of Things

Characteristics

- Event Driven
- Ambient Intelligence
- Flexible Structure
- Semantic Sharing
- Complex Access Technologies

Internet of Things
Why Internet of Things

- Dynamic control of industry and daily life
- Improve the resource utilization ratio
- Better relationship between human and nature
- Forming an intellectual entity by integrating human society and physical systems
Why Internet of Things (ii)

Flexible configuration, P&P...

Universal transport & internetworking

Accessibility & Usability?

Acts as technologies integrator
Epoch of IOT

MIT: Auto-ID-Center

ITU: ITU Internet Reports

IBM: Smart Planet

Obama: Business Round Table

IBM: Smart Planet, Winning in China

Wen Jiabao: sensing China
Premier Wen and Sensing China

- Premier Wen visited Wuxi in August 7, 2009.
- He proposed “Sensing China”.
1965 Main Frame
1980 PC
1995 Internet
2010 ?…

15-Year Law
The Application of IoT(1)

- Regional Office
- House
- Transportation Vehicle
- Virtual Environment
- Equipment in public place
- Biosensor taken by people
The Application of IoT (2)

Scenario: shopping

(2) When shopping in the market, the goods will introduce themselves.

(1) When entering the doors, scanners will identify the tags on her clothing.

(4) When paying for the goods, the microchip of the credit card will communicate with checkout reader.

(3) When moving the goods, the reader will tell the staff to put a new one.
The Application of IoT(3)

Scenario: Health Care

- Various sensors for various conditions
- Example ICP sensor: Short or long term monitoring of pressure in the brain cavity
- Implanted in the brain cavity and senses the increase of pressure
- Sensor and associated electronics encapsulated in safe and biodegradable material
- External RF reader powers the unit and receives the signal
- Stability over 30 days so far
The Application of IoT(3)

Scenario: Health Care

• National Health Information Network, Electronic Patient Record

• Home care: monitoring and control
  Pulse oximeters, blood glucose monitors, infusion pumps, accelerometers, ...

• Operating Room of the Future
  Closed loop monitoring and control; multiple treatment stations, plug and play devices; robotic microsurgery
  System coordination challenge

• Progress in bioinformatics: gene, protein expression, systems biology, disease dynamics, control mechanisms
The Application of IoT(4)

Scenario: Intelligent Home

- Remote monitor for smart house
- Remote control for smart appliance
The Application of IoT(5)

**Scenario: Transportation**

- A network of sensors set up throughout a vehicle can interact with its surroundings to provide valuable feedback on local roads, weather and traffic conditions to the car driver, enabling adaptive drive systems to respond accordingly.
- This may involve automatic activation of braking systems or speed control via fuel management systems. Condition and event detection sensors can activate systems to maintain driver and passenger comfort and safety through the use of airbags and seatbelt pre-tensioning.
- Sensors for fatigue and mood monitoring based on driving conditions, driver behaviour and facial indicators can interact to ensure safe driving by activating warning systems or directly controlling the vehicle.
The Application of IoT(5)

Scenario: Transportation

- In 2005, 30 – 90 processors per car
  Engine control, Break system, Airbag deployment system
  Windshield wiper, Door locks, Entertainment system
- Cars are sensors and actuators in V2V networks
  Active networked safety alerts
  Autonomous navigation
- Future Transportation Systems
  Incorporate both single person and mass transportation vehicles, air and ground transportations.
  Achieve efficiency, safety, stability using real-time control and optimization.
The Application of IoT

Scenario: Monitoring the Environment
State of the Art of IoT

Enabling Technologies

RFID
To identify and track the data of things

Sensor
To collect and process the data to detect the changes in the physical status of things

Smart Tech
To enhance the power of the network by devolving processing capabilities to different part of the network.

Nano Tech
To make the smaller and smaller things have the ability to connect and interact.
Sensor Technology

The ability to detect changes in the physical status of things is essential for recording changes in the environment.

Wireless sensor technology play a pivotal role in bridging the gap between the physical and virtual worlds, and enabling things to respond to changes in their physical environment. Sensors collect data from their environment, generating information and raising awareness about context.

Example: sensors in an electronic jacket can collect information about changes in external temperature and the parameters of the jacket can be adjusted accordingly
State of the Art of IoT

Research Groups

1. MIT Auto-ID Lab & EPC Global.
   - Stanford University
   - Georgia Institute of Technology
   - Cambridge Univ

2. EPFL & ETH Zurich Information and Communication Systems Research Group
   - Chemnitz University of Technology VSR Group

3. Nokia
   - SAP
   - IBM
   - GOOGLE
   - AMBIENT
   - Metro Group
   - Siemens
   - Sun
   - Cisco
   - GE
State of the Art of IoT

Figure 4 – The Internet of Things – from idea to market

R&D
- Private Investors & National Initiatives
- AIT RFID
- DARPA
- EU Framework program
- ISO/IEC 18000
- ISO/IEC 14443
- NFC Forum
- National u-initiatives
- APT/ASTAP
- Intel
- APEC TEL
- US DARPA
- Bluetooth Consortium
- University of California, Berkeley
- ZigBee Alliance
- Hibiki Consortium

Science & Research
- MIT (ex. Auto-ID center)
- Georgia Technology institute

Manufacturing
- Texas Instruments
- Verione
- Innovative
- Precision Dynamics
- OAT Systems
- IBM
- Nokia
- Think Magic
- ADT Security

Production
- Versatile
- MasterCard
- Tyco Retail Solutions Group
- JCB Corporation

Service provisioning
- NTT DoCoMo
- Hughes (satellite connection)
- Intel Research Lab Berkeley
- Digital Eastern, Melexis, Intersema (sensors)

Network operation
- McDonalds
- Tesco
- Chang Gung Memorial Hospital
- PayPass at McDonald’s restaurants in the US
- Patients RFID wristbands, Taiwan, China
- Item-level tracking across the SCM in the UK
- Mobile payments via FeliCa chip in Japan
- Great Duck Island Habitat Monitoring in the US

Market
- Lead users
- Examples of specific applications

Source: ITU
The Challenge of IoT

Total challenge of IoT

1. Technological Standardization in most areas are still remain fragmented.
2. managing and fostering rapid innovation is a challenge for governments
3. privacy and security
4. Absence of governance
The Challenge of IoT

How to convincing users that the IoT technology will protect their data and privacy when tracking

Potential Solutions

- Legal & Regulatory
- Technical Control
- Social Ethic
- Market Self-regulation
IoT and WSN

× WSN is IoT,  IoT aka WSN  ⇒  IoT = WSN

× IoT aka RFID + PerCom

✓ IoT is not WSN  IoT ≠ WSN
  IoT contains WSN  IoT ≥ WSN
IoT and WSN

- Things are diverse

- They might be individual like water, soldiers, trees...

- They also be a set of individuals like ocean, battlefield, forest, ...
IoT and WSN

We concern not only about water, tree and soldier, but also about ocean, forest and battlefield.
IoT and WSN

So we have ocean monitoring, Forest management, battlefield control.
When WSN is Used
To Connect digital world and physical world
IoT and CPS

CPS

C1

C2

Cn

P1

P2

Pn

C = C1 ∨ C2 ∨ ... ∨ Cn

P = P1 ∨ P2 ∨ ... ∨ Pn

Internet or Cyber world

IoT
## IoT and Pervasive Computing

<table>
<thead>
<tr>
<th>Needed Capability</th>
<th>Technology Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Cheap solar energy</td>
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<tr>
<td></td>
<td>Rural wireless communications</td>
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<tr>
<td></td>
<td>GM crops</td>
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<tr>
<td></td>
<td>Filters and catalysts</td>
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<tr>
<td></td>
<td>Cheap autonomous housing</td>
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<tr>
<td>Medium</td>
<td>Rapid bioassays</td>
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<tr>
<td></td>
<td>Green manufacturing</td>
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<tr>
<td></td>
<td>Ubiquitous RFID tagging</td>
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<tr>
<td></td>
<td>Hybrid vehicles</td>
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<tr>
<td>High</td>
<td>Targeted drug delivery</td>
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<tr>
<td></td>
<td>Improved diagnostic and surgical methods</td>
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<tr>
<td></td>
<td>Quantum cryptography</td>
</tr>
<tr>
<td>Very High</td>
<td>Ubiquitous information access</td>
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<tr>
<td></td>
<td>Tissue engineering</td>
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<tr>
<td></td>
<td>Pervasive sensors</td>
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<td></td>
<td>Wearable computers</td>
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</tbody>
</table>
CPS and Pervasive Computing

All such buzzwords refers to the same balloon. When it is blasted to large size, it is called **Smart Planet**; when to middle size, it is called **CPS**; When to small size, it is called **pervasive or embedded system**.
Internet of Things vs. Cloud Properties

**Internet of Things**
- Real world
- Small things
- Constrained devices
- Unreliability

**Cloud**
- Virtual world
- Big things
- Unlimited capabilities
- Availability
Internet of Things, Cloud and Services

- **Internet of Things enables**
  - High-resolution management
  - Real-world control
  - Adaptive processes

<table>
<thead>
<tr>
<th>IoT Issue</th>
<th>Possible Solution</th>
</tr>
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<tbody>
<tr>
<td>Heterogeneity</td>
<td>Services as abstraction layer</td>
</tr>
<tr>
<td>Application Development</td>
<td>Mash-up of services</td>
</tr>
<tr>
<td>Solution Deployment</td>
<td>Support through XaaS models</td>
</tr>
<tr>
<td>Producing a lot of data</td>
<td>Processing of large data quantities in the cloud</td>
</tr>
</tbody>
</table>

IoT, Cloud, and Services are **complementary aspects** of a Real World Internet
2 Examples

- For the public and the society
- For business and enterprises
Example 1: Pachube

- "The Internet of Things Real-Time Web Service and Applications"
  - Platform to connect sensors and other hardware
  - Platform to build IoT services and applications
  - RESTful APIs

Source: [https://pachube.com/](https://pachube.com/)
After the Fukushima Disaster on Pachube
Many People Connected Radiation Sensors...
Cool, but ...

- Data quality of various sources
  - Accuracy of each data point
  - Sensor reliability and availability
  - Time of measurement
  - Important for trust!
- Unit jungle:
  - nGy/s, mSv/h, ´ Sv/h, Bq/kg, cpm ...
  - Sometimes misleading, sometimes just hard to compare...
- Mix of data sources
  - Real sensors
  - Virtual sensors (data scraping from web pages, e.g.,
    http://www.housshasen-pref-ibaraki.jp/present/result01.html)
Business Web
A Platform and Marketplace for Business Services

The Business Web is a cloud-based business environment that provides access to the necessary infrastructure, applications, content, and connectivity to deliver end-to-end business services optimized for mobility and ease of participation.
Business Web:
First-class Internet of Things Integration
M2M Scenario – Ice Cream Cabinets

• The application provides consumer products companies with detailed information about the location and status of its ice cream cabinets.

• This information can be used to find these cabinets, supply them with new ice cream in time, and monitor their temperature in order to avoid ice cream becoming bad due to a defective ice cream cabinet.

• The ice cream cabinets become smart items that monitor their energy consumption, send alarms, and become an active part in the companies operation processes as well as sustainability efforts.
IoT Configuration

- 2.5 million ice cream cabinets
  - Worldwide distributed
  - Biggest growth markets: China and India

- Sensoring
  - Need to refill
    - Avoid stock-outs
  - Location
    - Reliably find and refill
  - Temperature / power outage
    - Detect failures and avoid product loss
  - Behavioral statistics
    - Conclude conversion rate

- Estimated business value: >5% increased sales
IoT Integration into Business Processes

Roles and processes
• CPG Backend
  • Operational BI on supply chain efficiency
  • User behavior monitoring and campaign efficiency
• 3rd Party Supplier
  • Dispatcher: Improved planning of daily logistics processes
    • Get refill priorities and alarms on power outage and temperatures
  • Truck Driver: Guidance and real-time integration into process
• Store Owner
  • Push alarms to store owners for immediate actions
    • Resolve power outage / close lid to save energy
• Consumer
  • Guidance to next ice cream cabinet (source of happiness)

3rd Party Supplier

Consumer
Augmented Reality App:
Guide me to the next ice cream opportunity
Business Value

Ice Cream Business is a 60+ billion market
- Highest margin business in food CPG
  - 10.5%
- Unilever
  - 10+ billion in ice cream sales
  - Market leader in out-of-home ice cream business
    - 30% market share
    - 2/3 is out-of-home business
  - ICC scenario estimated benefit is 45 million additional profit per year
- Phase 1: Pilot
  - 500 ICCs in Germany, 50 mobile users
- Phase 2:
  - 10,000 ICCs in Germany, 1,000 users
- Phase 3:
  - Replacing 200,000 ICCs yearly worldwide.
Short Summary

• Internet of Things, Cloud Computing and Services are all aspects of a (Future) Internet
  • Strengths of each can and should be combined
• Examples of successful combinations exist
  • Both in the public and the business domain
• We are at the beginning of an interesting journey
  • Many challenges still lie ahead
Road is Difficult, but Future is Bright

- Any TIME
- Any PLACE
- Any THING