UCDAVIS
UNIVERSITY OF CALIFORNIA

Internet of Things

Senior Design Project Course

Introduction – Part 1

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Required Reading:

- F. Samie, L. Bauer and J. Henkel, "**IoT technologies for embedded computing: A survey**," *2016 International Conference on Hardware/Software Codesign and System Synthesis (CODES+ISSS)*, Pittsburgh, PA, 2016, pp. 1-10.
  - http://ieeexplore.ieee.org/document/7750968/

- No Review is required for this paper!

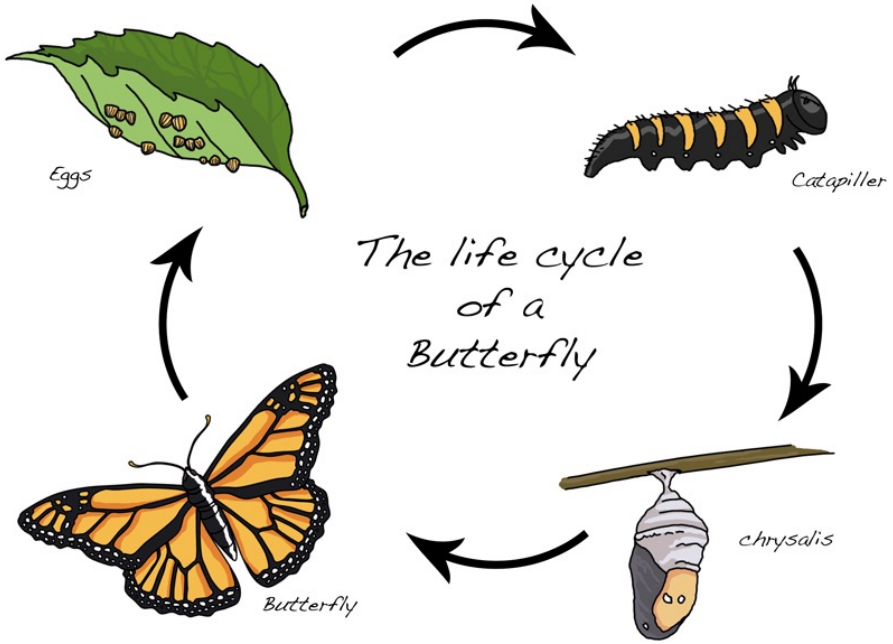
Flow of Data in Internet of Things (Review)

Image source: http://www.cchc.cl/informacion-a-la-comunidad/industria-de-la-construccion/personaje/

Life Cycle of Data at Edge

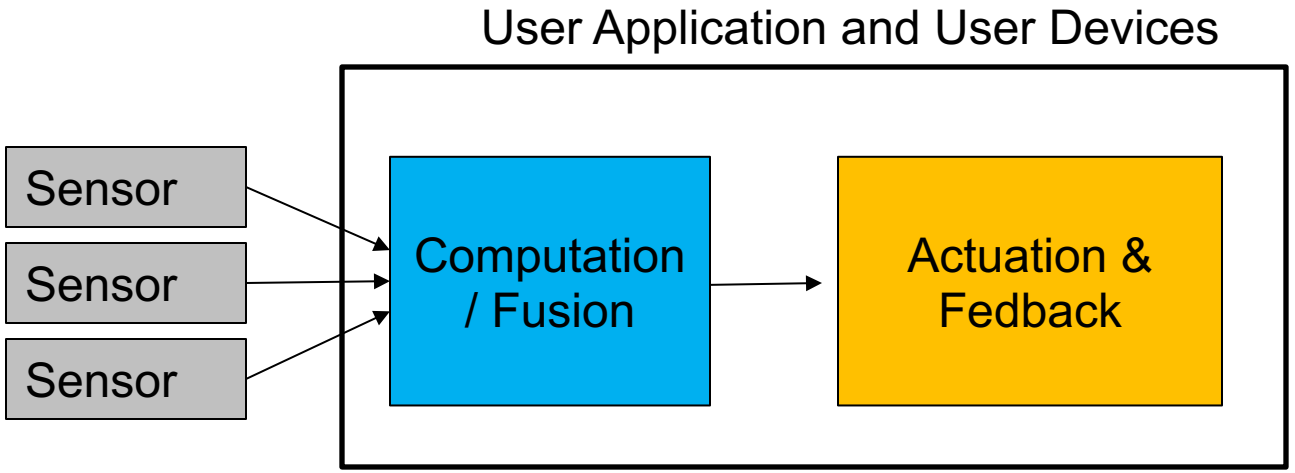
- The edge solutions could be
  - Memoryless & Short Cycle
  - With memory & Short Cycle
  - With memory and Long Cycle

  - What does it mean?



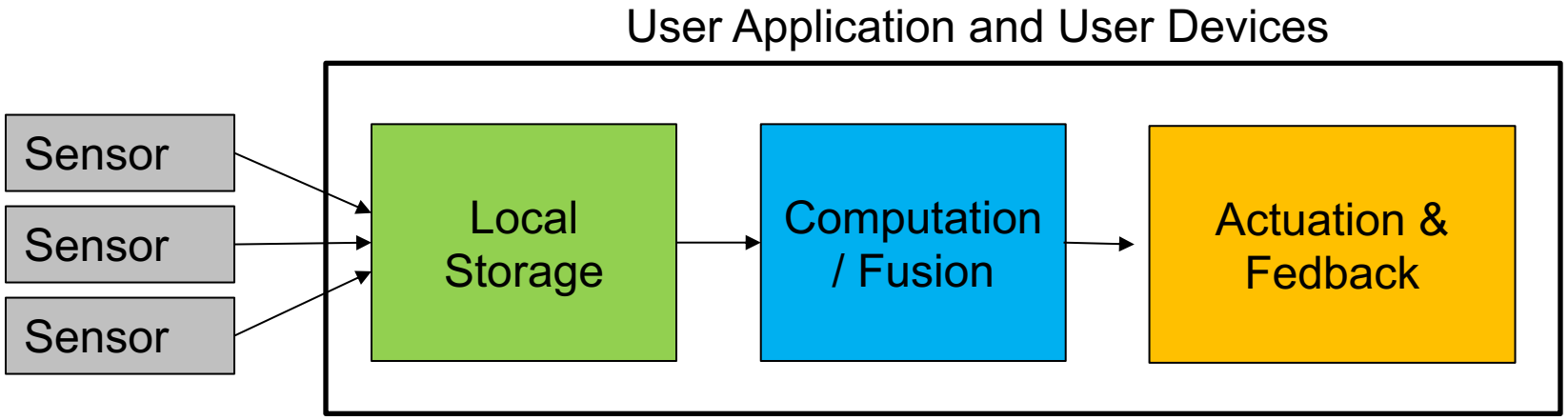
Memoryless and Short Cycled

- Data is sensed
- Sensed data is fused and is subjected to some form of computation
- Based on the computation result, an action is actuated!
- Data is then disregarded!



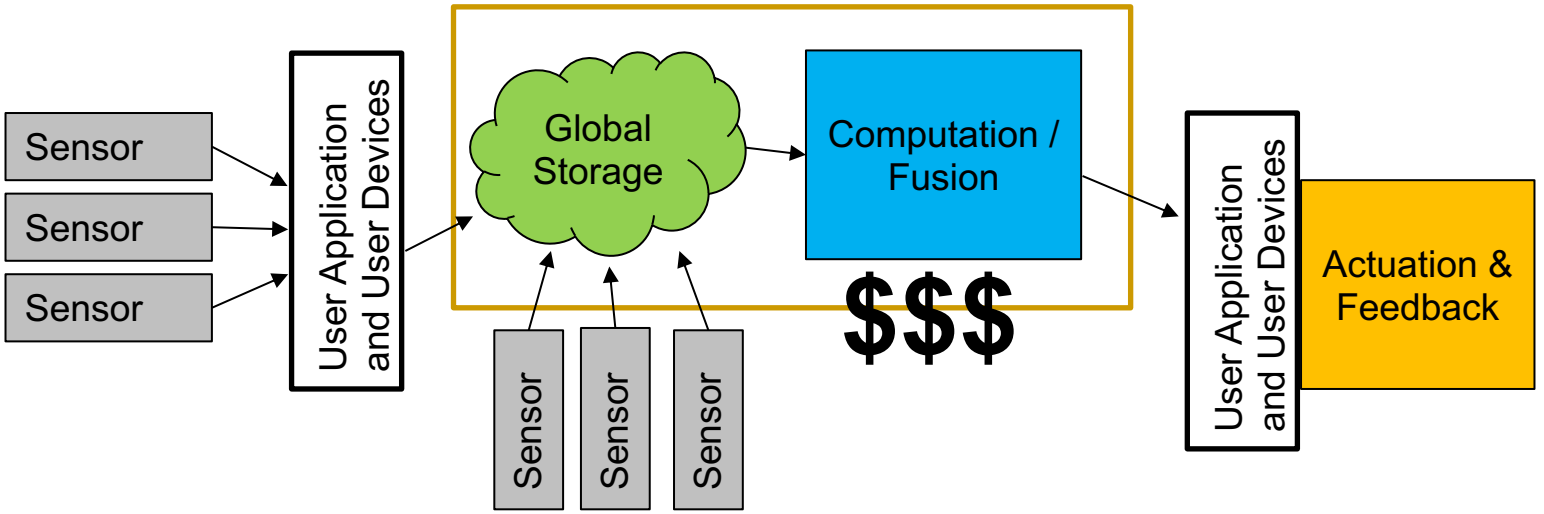
With Memory and Short Cycle

- Data is sensed in regular/irregular intervals
- Sensed Data is stored locally
- Sensed data is fused and is subjected to some form of computation
- Based on the computation result, an action is actuated!



Long Cycle (Most Desired)

- Local sensing, processing and actuation happens as before!
- Processed or sample data is communicated to the cloud service(s).
- Sensed data from many sources are aggregated, fused and analyzed to extract knowledge.
  - Events are detected, trends are detected, predictions are made
- Feedback is sent to selected edge nodes, improving services
- Knowledge and history is stored for improving or enabling future services.



IoT Big Data

- **A Poor man definition**: An enormous amount of data, including streams of data, audio, or video, will be generated from IoT devices
- Computation and processing of data should be migrated to different underlying computing layers in the IoT chain
- Available layers are **Device**, **Gateway**, **Fog**, **Cloud**
- When deciding where computation take place, one should consider:
  - **System objectives**
    - (e.g. real-time requirement, energy efficiency, etc.)
  - **System specifications**
    - (e.g. energy consumption for data processing and data transmission on IoT device, communication bandwidth, transmission delay, etc.)

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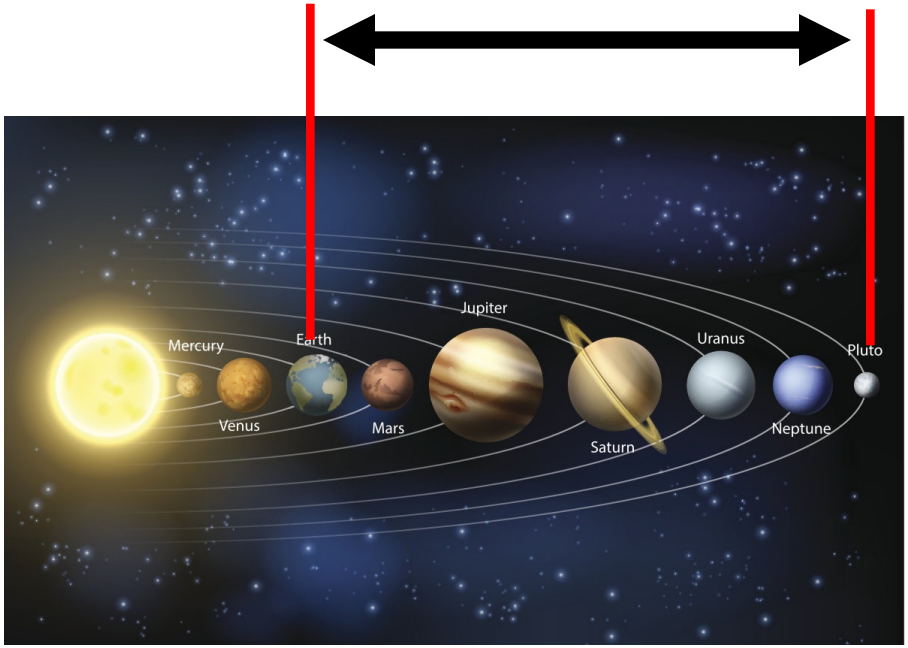
Information on Cloud!

4000 Exabyte

=

160x of the distance between Earth and Pluto



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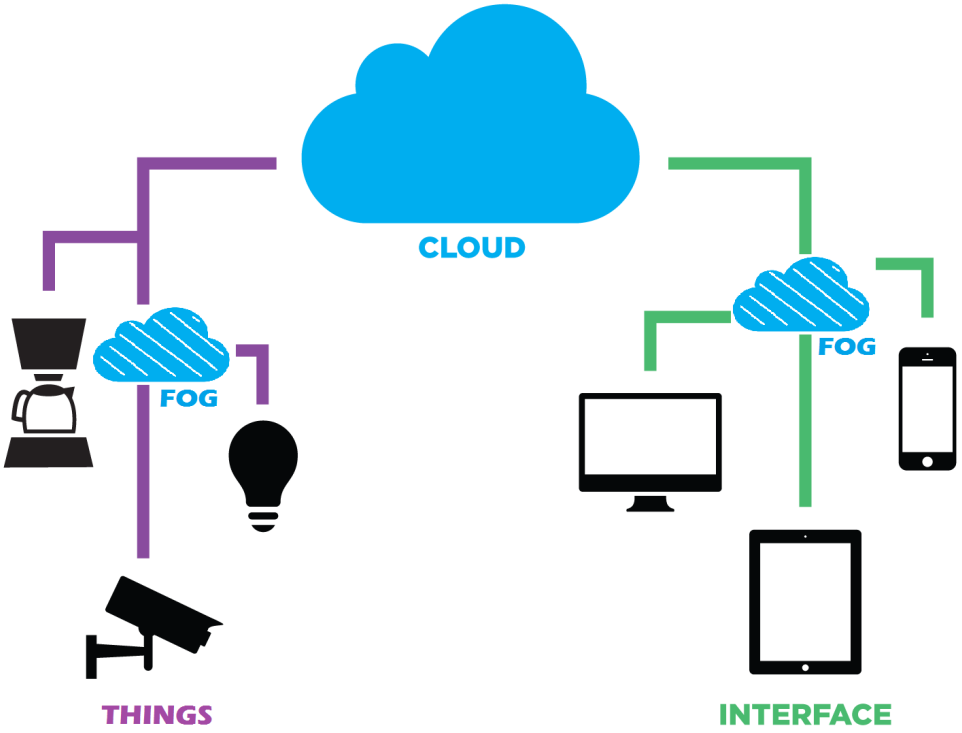
Fog Computing

- Number of connected devices increases exponentially
- Amount of data being generated grows exponentially
- Using smart devices, as apposed to a primitive sensor
- Handling the interpretation logic rather than requiring a trip to the cloud



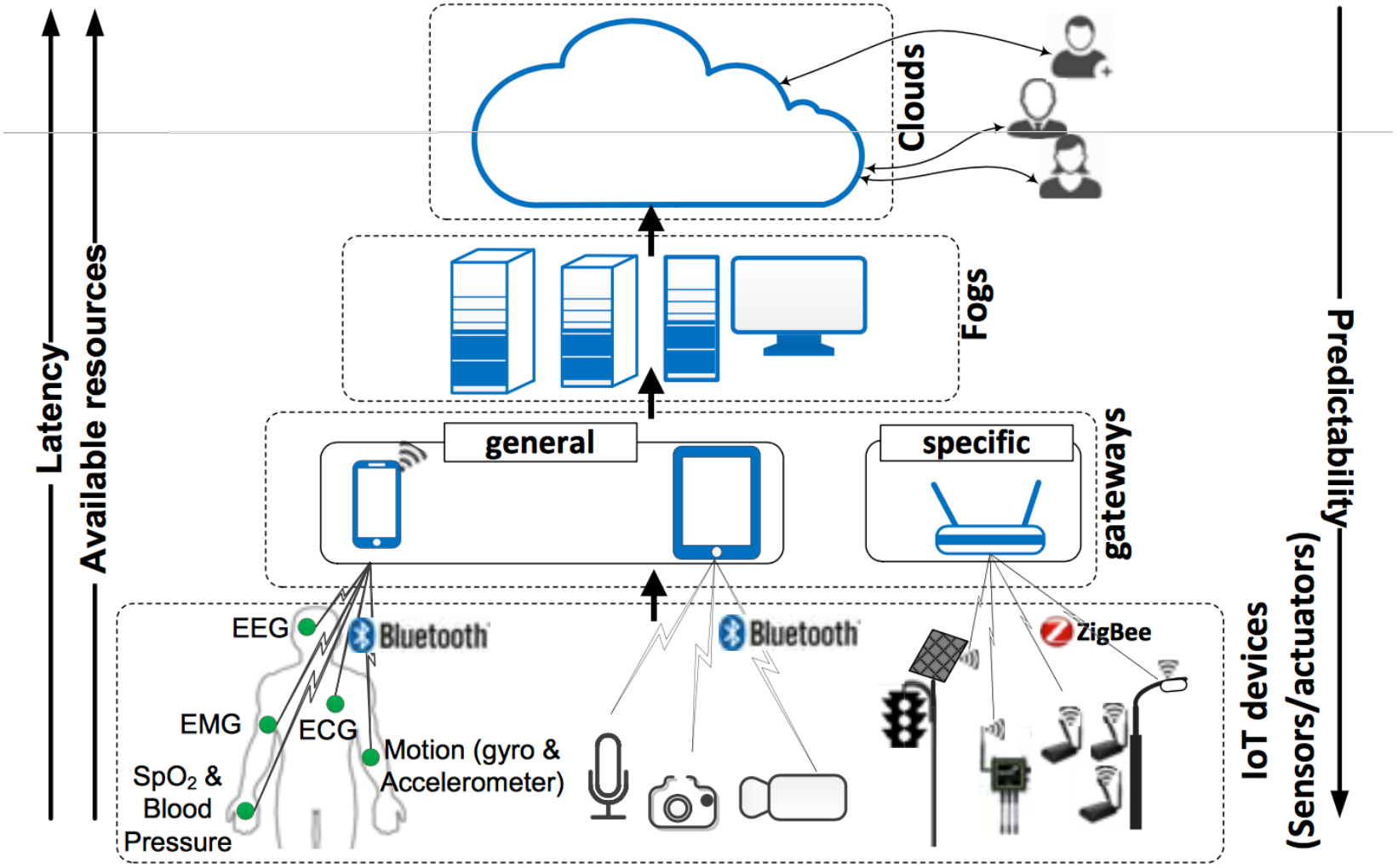
Fog vs Cloud Computing

- **Cloud Computing**
  - Sending data to the cloud for processing
  - A group of computers and servers interconnected through the web to form a network

- **Fog Computing**
  - A middle layer between the cloud and the hardware to enable more efficient data processing, analysis and storage
    - a distributed infrastructure
  - Reduces the amount of data which needs to be transported to the cloud
  - Make the data (to be transferred) more meaningful!

- **Fog is the cloud close to the ground**

IoT Chain Computation Layers



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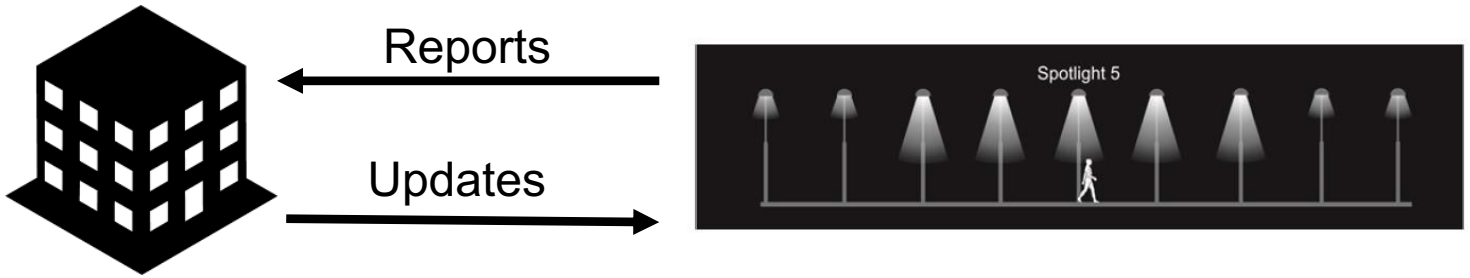
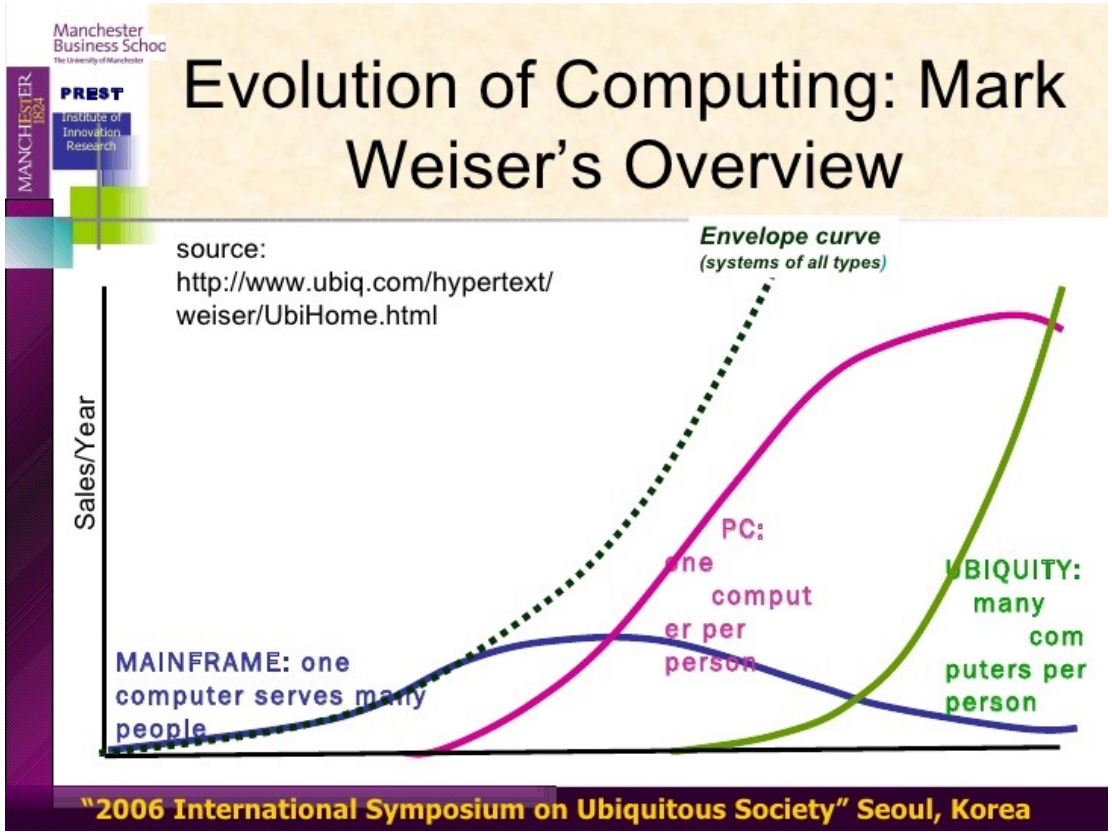
Fog Computing Example

- Smart lighting system
  - operates based on movement.
  - Sense → process data → movement detected → lights on!
  - Sense → process data → no movement → lights off!
  - data & resulting decisions are best processed at the edge
  - Energy efficiency reports and on/off logs are reported to the managing service/company
  - Reported data provides a "bigger picture" to the reporting system in the cloud
  - Knowledge is extracted
  - Managing service updates the processing nodes for better service or higher efficiency.



Ubiquitous (Pervasive) Computing

- **Mainframe**: many people share one computer
- **Personal computer**: one person uses one computer
- **Ubiquitous computing**: many computers serve each person.

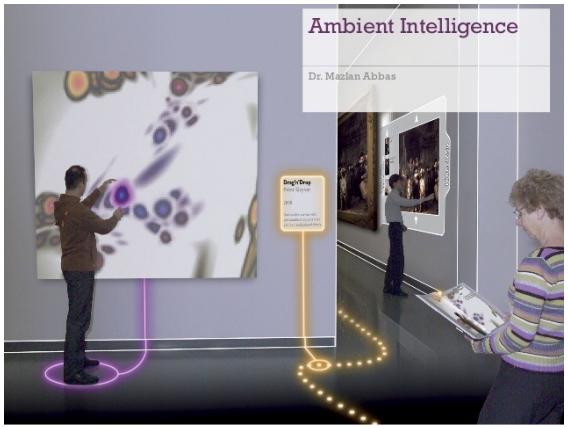


Ambient Intelligence (Aml)

- Ambient intelligence paradigm builds upon pervasive computing
- Electronic environments that are sensitive and responsive to the presence of people.
- Devices work in concert to support people in carrying out their everyday life activities, tasks and rituals in an easy, natural way
- Using information and intelligence that is hidden in the network connecting these devices
- The technology disappears into our surroundings until only the user interface remains perceivable by users

Ambient Intelligence

- Characterized by systems and technologies that are:
  - **Embedded:** many networked devices are integrated into the environment
  - **Context aware:** devices can recognize you and your situational context
  - **Personalized:** devices can be tailored to your needs
  - **Adaptive:** can change in response to you
  - **Anticipatory:** can anticipate your desires without conscious mediation



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Relation between #Services and #Devices

- The relation between the # of devices and # of service and applications
  - **One-to-One**: One IoT device per service
    - E.g. healthcare monitoring that captures real time bio-signals
  - **One-to-many**: One IoT device provides multiple services.
    - E.g. smart watch with multiple sensors to track user's physical activity, heart rate, location
  - **Many-to-one**: physically distributed devices providing a single service.
    - E.g. distributed smart cameras for video surveillance
    - Should be optimized with respect to
      - high communication rate between devices
      - large amount of redundancy
  - **Many-to-many**: multiple devices shared between multiple applications and services
    - E.g. Smart Citizen where multiple IoT embedded devices are geographically distributed to gather information for the applications that report temperature, humidity, noise level, and air pollution

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Where to Compute?

- **Device centric:**
  - microcontroller in an IoT device can be exploited to perform the computation.
  - challenges are
    - scarce resources on IoT devices
    - runtime decision
- **Gateway centric**
  - gateway devices which are used to settle the heterogeneity between different networks and Internet usually have more computational power
    - This scheme has been used for medical and healthcare monitoring application
    - challenge
      - guarantee the availability and deadline constraints

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Where to Compute?

- **Fog centric**
  - Fogs provide more computational power compared to IoT embedded and gateway devices and have less latency compared to the cloud servers
- **Cloud centric**
  - massive data storage volume, huge processing resources
  - challenges
    - Size of data (big data)
    - scalability
    - high energy cost
    - latency
    - bandwidth
    - availability

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IoT Companies

- **SoC era (2000-2016)**
  - larger but fewer companies
  - integration of many components
  - Chip design
  - Focus on developing new IP
  - More general purpose
    - Example: Snapdragon → Qualcomm

- **IoT era (2014 – 202X)**
  - Smaller size but larger number of companies
  - Integration of few necessary components
  - System design
  - Focus on usage of existing IP
  - Specific purpose