

# Integrating Cloud and Mobile Computing

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*when the large meets the small*

**Cloud Server = Brains**  
**Mobile + Sensors = Eyes, Ears, Mouth**  
**Robot = Hands + Legs**

- Cloud servers have (almost) unlimited resources. Cloud has sufficient computation capability for recognition, analysis, and reasoning. Therefore, cloud = brain.
- However, a brain needs eyes, ears, mouths, hands, and legs.
- Mobile systems, robots, and sensors have interfaces with the physical world and can play the roles of eyes, ears, hands ...



**Future Information Technology = Cloud + Mobile + Robot + Sensors**

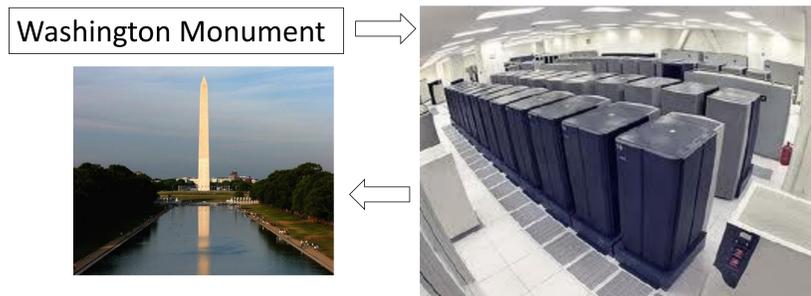
| Feature             | Cloud        | Mobile  | Robot        | Sensor            |
|---------------------|--------------|---------|--------------|-------------------|
| performance         | unlimited    | medium  | low          | very low          |
| storage             | unlimited    | GB      | MB           | KB                |
| energy              | grid powered | battery | battery/fuel | battery/renewable |
| data rate           | Gbps         | Mbps    | M, Kbps      | Kbps              |
| dependability       | yes          | no      | no           | no                |
| elasticity          | yes          | no      | no           | no                |
| user interface      | no           | yes     | no           | no                |
| portable            | no           | yes     | maybe        | maybe             |
| environment sensors | no           | yes     | yes          | yes               |
| camera              | no           | yes     | yes          | maybe             |
| mobility            | no           | no      | yes          | usually no        |
| autonomous          | no           | no      | yes          | no                |
| actuator            | no           | no      | yes          | usually not       |
| handle hazards      | no           | no      | yes          | may detect        |

**Challenges**

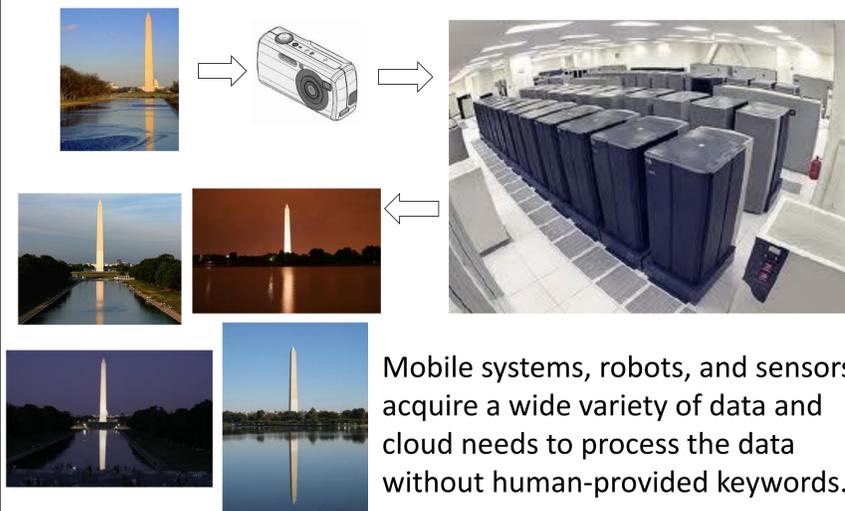
- Develop programming models and tools to integrate different systems. They have complementary strengths and weaknesses, significantly different programming models, languages, and OS.
- Design execution environment for sensor-triggered real-time simulations. Simulations of physical world are often highly parallel and can take advantage of cloud's elasticity.
- Protect data collected from mobile systems, robots, and sensors. Privacy is a major concern when personal data may be obtained. Protection schemes must be lightweight because of limited energy and low performance.
- Create education programs teaching students how to use cloud, program cloud, and manage cloud. Cloud may reduce barriers for diversified groups of students to pursue careers in computing.

**Content-Based Multimedia Information Retrieval**

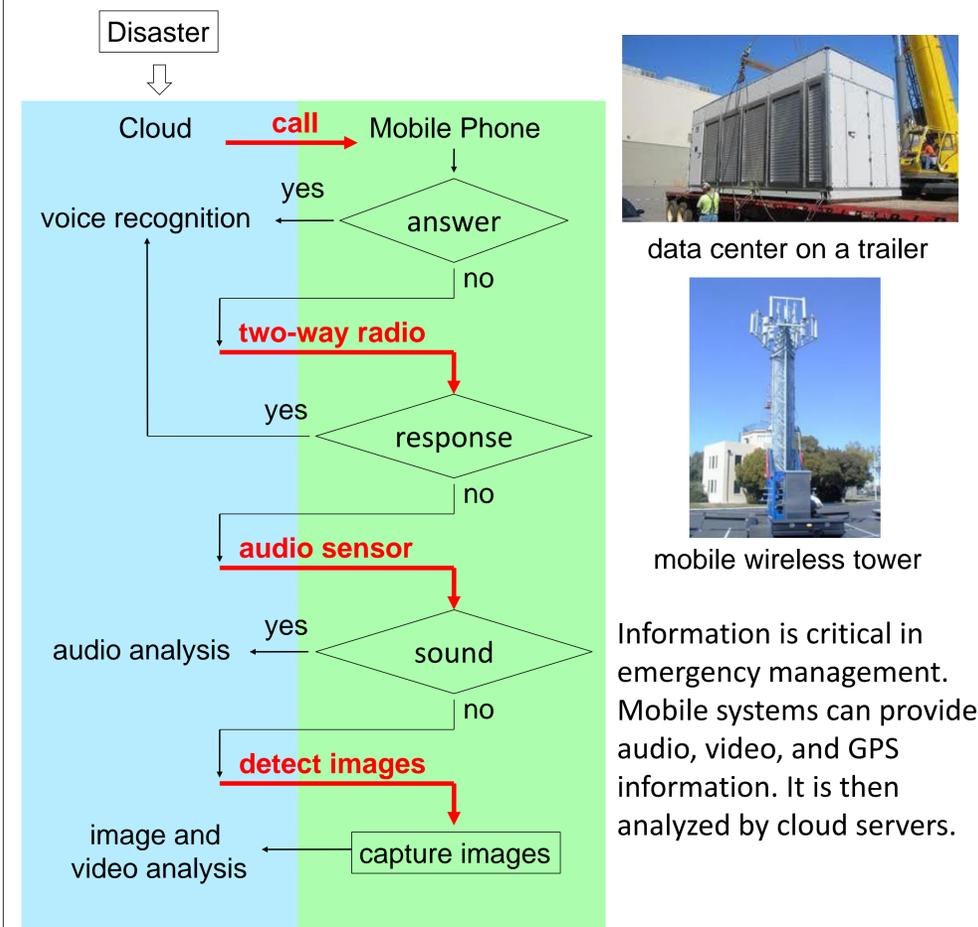
- Existing information retrieval = keyword based search



- Content-based multimedia information retrieval = use multimedia to retrieve information



**Cloud + Mobile for Emergency Management**



**Cloud + Mobile Computing for Education**

- Cloud computing may reduce the barriers for students to pursue careers in computing
  - ⇒ Cloud computing will generate many job opportunities.
  - ⇒ Schools do not need to purchase, manage, and maintain expensive high-performance computers; nor do they need to purchase and update software.
  - ⇒ Students can access cloud servers anywhere.
  - ⇒ Cloud + mobile offers new approach for solving problems.
- Cloud computing allows educators to share resources, such as lecture videos, on-line tutorials, program analysis and homework grading. By using cloud computing, high-school teachers can utilize the resources developed at universities.
- Combing cloud and mobile computing, students can learn any time and anywhere.
- Researchers and educators should collaborate to develop facilities that promote education using cloud computing.

**Representative Publications**

- Computation Offloading: IEEE Computer April 2010, ICPADS 2007.
- Trust and Privacy: HotPower 2010, ISLPED 2010, ICCCN 2009, ISLPED 2009.
- Autonomous Robot: IROS 2010, Automatica 2009, IEEE TRO 2006.