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Collaborative Information Processing (CIP) in Sensor Networks

Presentation at pHealth 2009 Workshop Session
"Personal Portable Devices and Sensor Networks"
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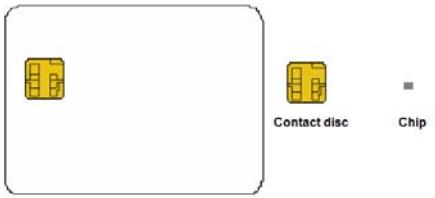
Outline

- Sensor network application 1 (eHealth)
- Sensor network application 2 (anti-intrusion system)
- Information processing requirement analysis in applications
- CIP overview in sensor networks
- CIP model in sensor networks
- Key issues on CIP in sensor networks
- Generic CIP implementation framework in sensor networks
- Further issues on CIP in sensor networks
- Conclusion

Sensor Network Application (eHealth)

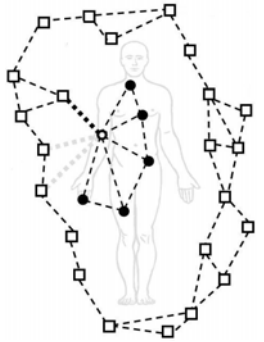
Physical Entities

Card



Portable Devices/Sensors

Sensor Networks

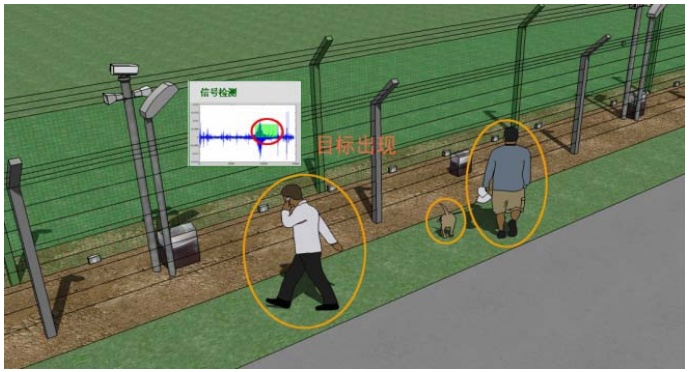


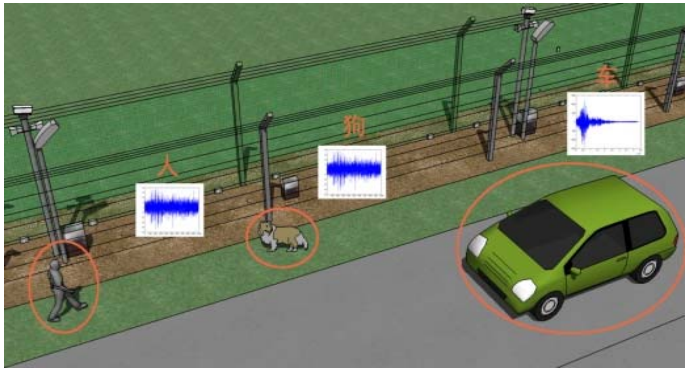
Data Features

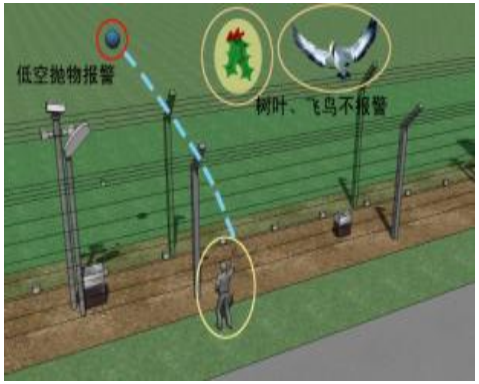
• Identification • Medical record • Administrative data	• Blood pressure • Body temperature • ECG • ...	• Fitness evaluation • Disease management • Danger alarming
➢ **Artificial** ➢ **Man-made** ➢ **“abstract”**	➢ **Physical** ➢ **independent** ➢ **respective** ➢ **“real”**	➢ **Aggregated** ➢ **Fused/Post-processed** ➢ **Personalized** ➢ **decisive**

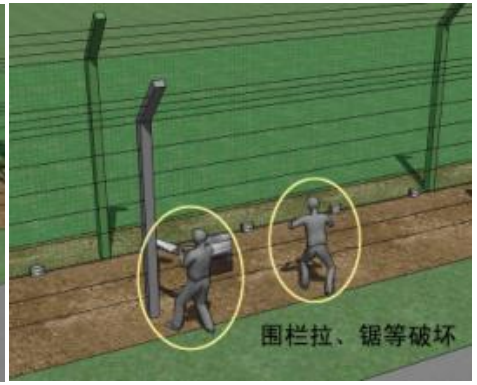
Sensor Network Application (anti-intrusion system)

- Different intruders
  - Person
  - Heavy wheeled vehicle
  - Light wheeled vehicle
  - Animals, ...
- Different intrusion behaviors
  - Object casting
  - Fence destroying
  - Climbing
  - Underground intrusion, ...









Information Processing Requirement Analysis in Applications

- Vital sign monitoring
- Basic life monitoring
- Trend analysis and alerting
  - Reliable event detection
  - Long time periodic monitoring
  - Adaptive processing
  - Pervasive monitoring
  - High-level information fusion
  - Personalized service providing
  - Context-aware Sensing
- Intruder detection
- Intruder classification
- Intruder localization & tracking
  - Extremely low false negative rate
  - Low false alarming rate (FAR)
  - Low time latency
  - Correct object classification
  - Low localization error
  - Maneuvering object tracking
  - Performance stability

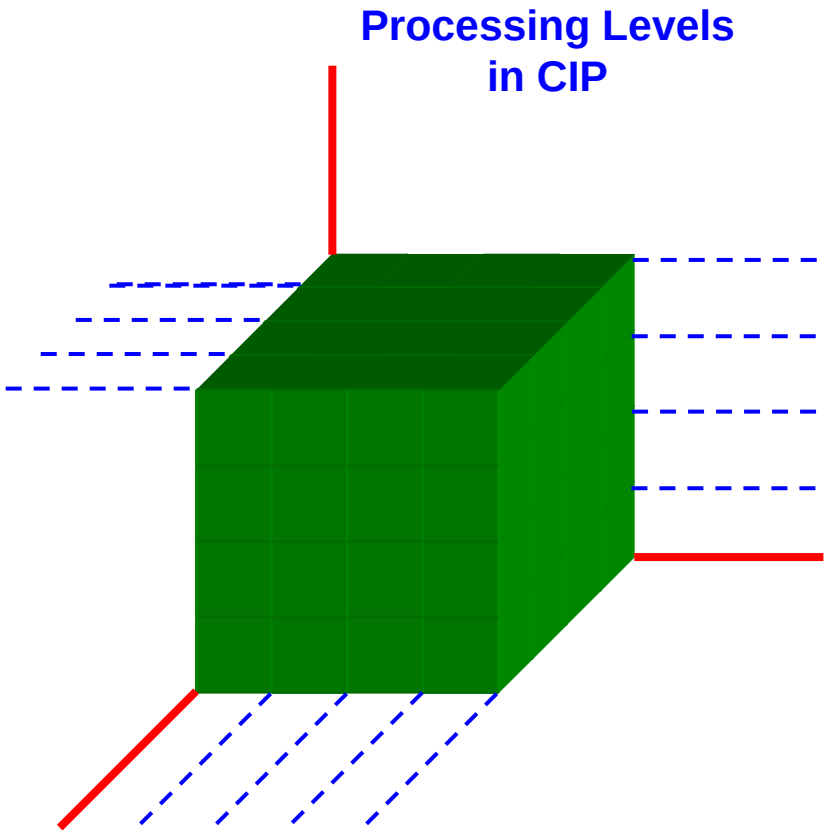
CIP Overview in Sensor Networks (1)

- Why we concern on collaborative information processing?
  - **Measurement is NOT the ultimate goal of sensor networks.**
    - The aim of sensor networks is to obtain information or knowledge from the physical world.
    - Information or knowledge can be extracted from sensor measurements.
    - Information processing translates sensor measurements into knowledge.
  - **Sensor network is NOT "Sensor + Network".**
    - Raw sensor measurement is just a straightforward kind of payloads.
    - In-network processing is implemented along with data communication.
  - **Information processing should NOT be applied only in a centralized manner.**
    - High efficiency using distributed proaeqqile
    - Ppmepessive accuracy requirement
  - **Information processing can NOT be fully covered by application layer.**
    - Dynamic node clustering/grouping along target trajectory
    - Dynamic node activation on event occurrence
    - Adaptation on sensing and communication capabilities

CIP Overview in Sensor Networks (2)

- CIP is an essential solution for **challenges** in sensor networks.
  - **Constrained resources**
    - Energy, communication bandwidth, computing, storage, size, cost, etc.
  - **High information sensing performance requirements**
    - Reliable target detection
    - Correct target classification
    - Accurate and fast target tracking etc.
  - **Integrated service providing**
    - Situation evaluation and prediction etc.
  - **Complicated application scenario & environment**
    - Random noise
    - Uncertain interference
    - Erroneous/unstable wireless link
    - Incorrect/inconsistent/incomplete sensor measurement

CIP Model in Sensor Networks (1)



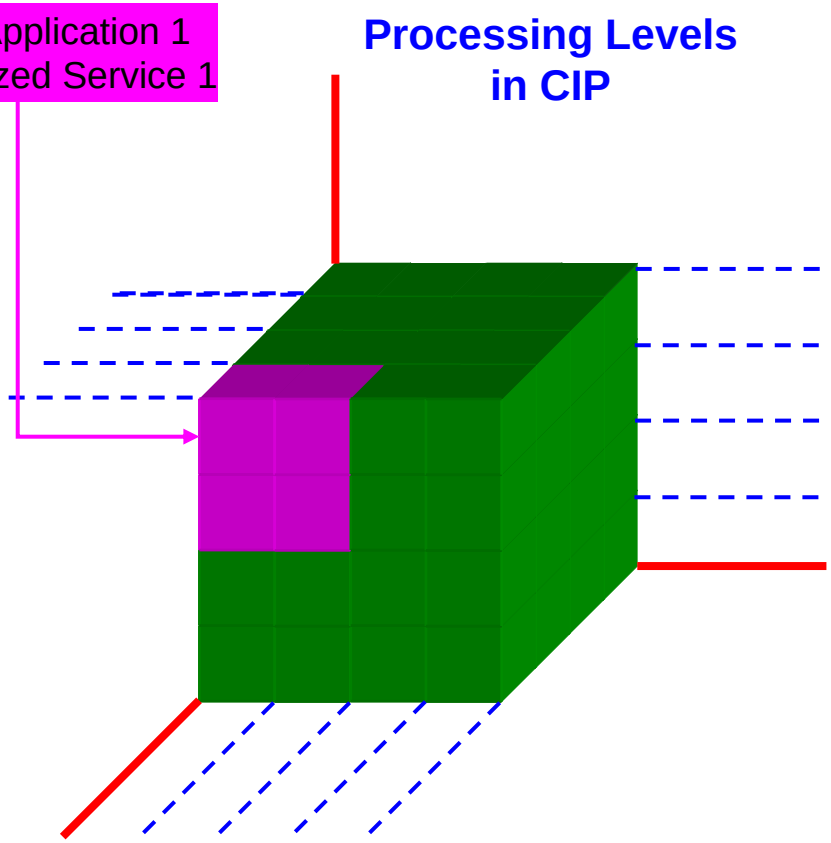
- Detection
- Localization
- Tracking
- ...

- Signal Level
- Feature Level
- Decision Level

- Blood pressure
- Respiration
- Body Temperature
- ECG
- Glucose
- Gait
- ...

- Sensor modalities
- Processing modules
- Nodes
- Clusters
- Subnets
- ...

CIP Model in Sensor Networks (2)



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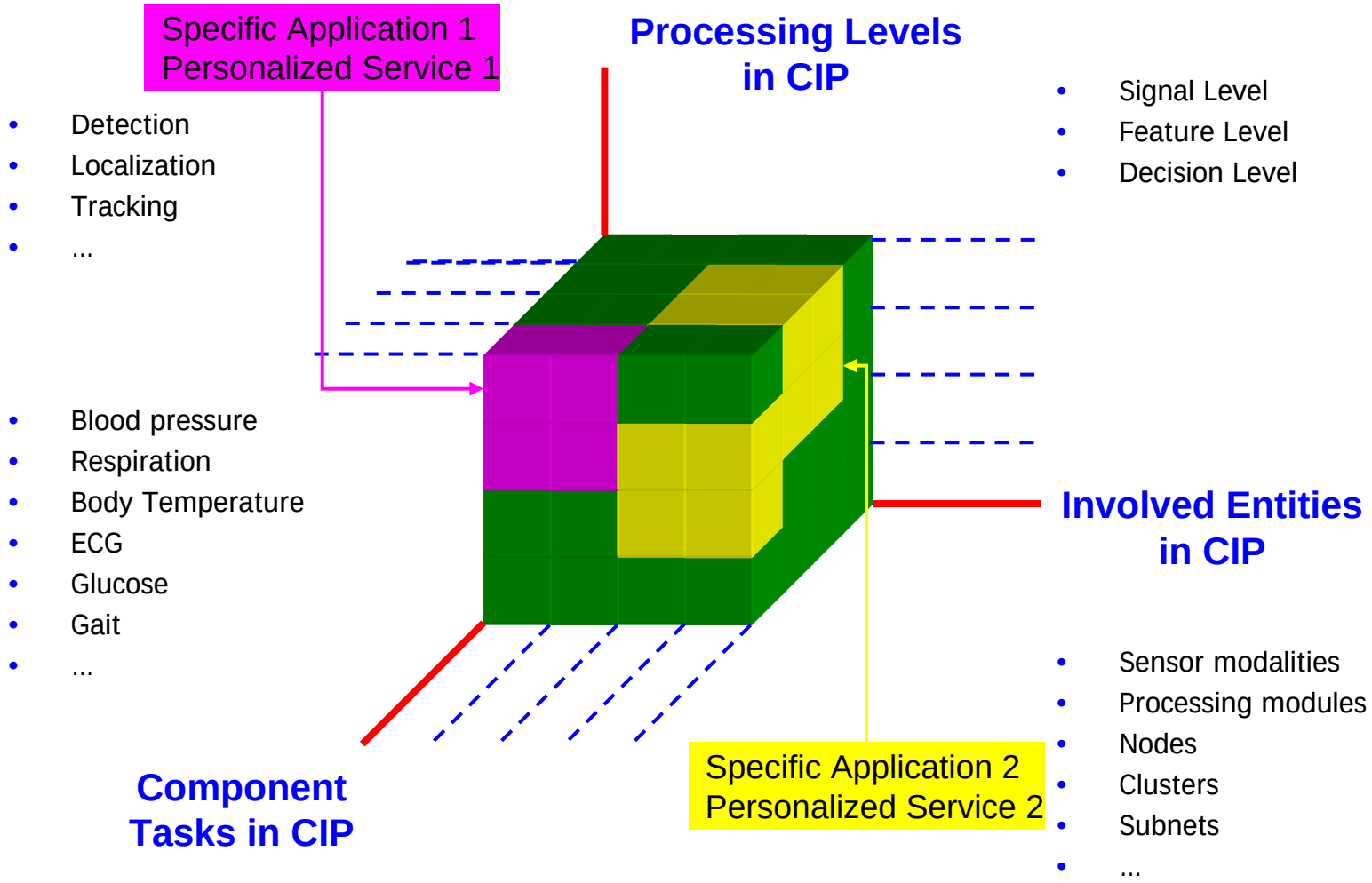
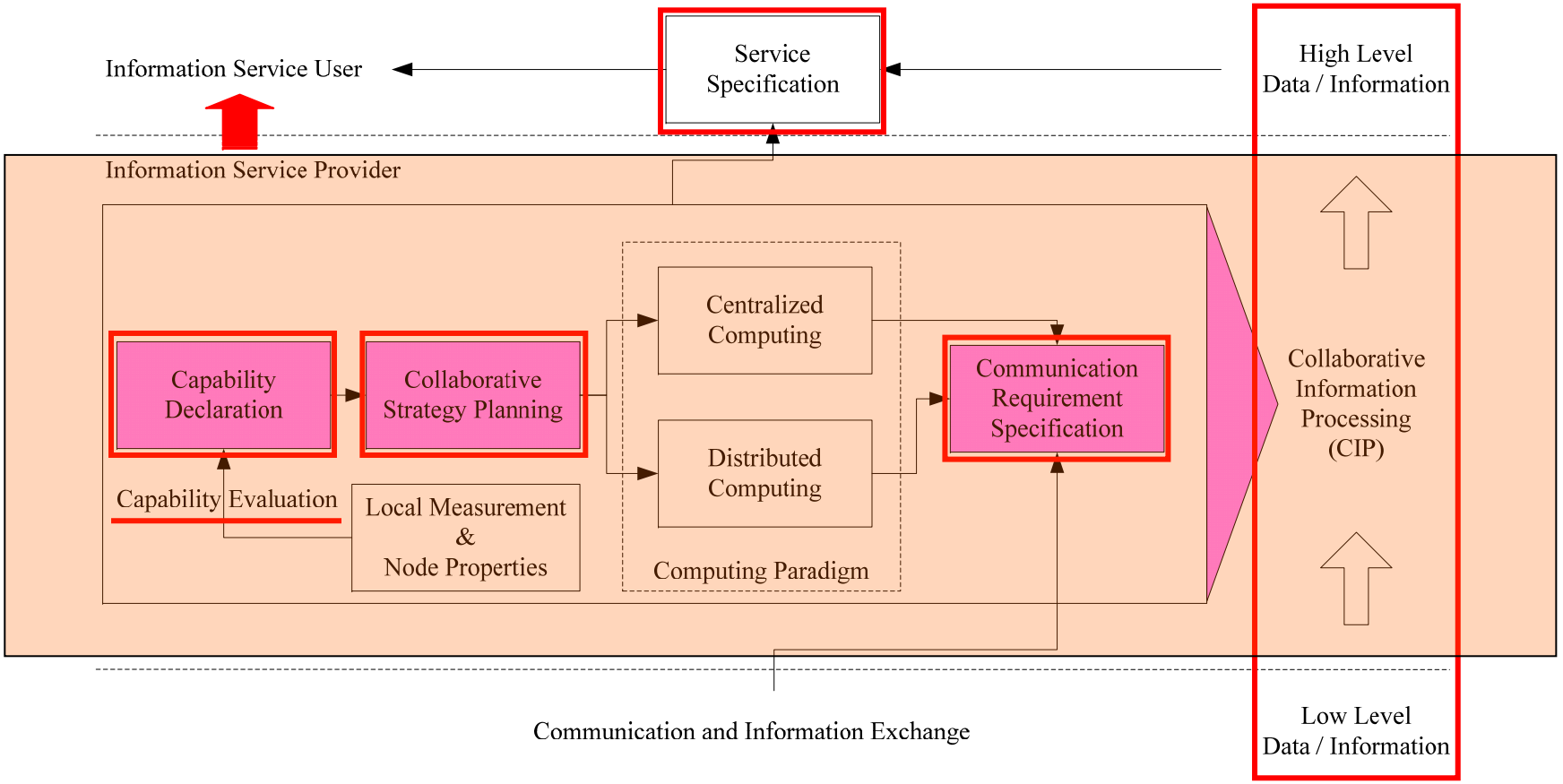
CIP Model in Sensor Networks (3)



Key Issues on CIP in Sensor Networks

- **Question 1: What** is the CIP objective?
  - — Service description and Service-to-task mapping
  - — Quality of Services (QoS)
- **Question 2: Who** should participate in CIP?
  - — Potential participants:
    - sensor modalities, algorithm modules, nodes, clusters, subnets, ...
  - — Capability evaluation:
    - Networking perspective: power, transmission range, bandwidth, ...
    - Sensing perspective: sensing range, SNR, information gain, ...
- **Question 3: What** is the rules in CIP?
  - — Strategy planning algorithms
    - Active/Sleep mechanism, dynamic networking, message exchanges, ...
    - information utility functions
- **Question 4: How** should CIP be implemented?
  - — Centralized or distributed computing
    - Leader selection, Mobile agent computing
  - — Communication requirements
    - Priority communication, Secure communication, multicasting, ...

Generic CIP Implementation Framework in Sensor Networks



Further Issues on CIP in Sensor Networks

- Environment-adaptive CIP
  - Environmental feature extraction
  - noise and interference characterization
- Coupling between autonomous networking and collaborative sensing
  - coupling principle
  - association methods
  - handshake mechanism
- Dynamic service and task mapping
  - Subtask assignment
  - Role transferring
- Data flow models in CIP
  - Data flow classification
  - Semantics, syntax and timing in data exchange

Conclusion

- CIP should be carefully designed to meet challenges in sensor networks from both the networking and the information sensing perspectives.
- The implementation of CIP in sensor networks involves considerations from different information processing levels, different entities and different component tasks.
- CIP closely relates networking with sensing in sensor networks.
  - For purpose of system efficiency, sensing method, network topology, node state and data transmission mechanisms etc. may be dynamically changed.
- CIP is an integral part in sensor network standardization.
  - A subgroup on CIP (PG4) has been established under the standardization working group on sensor network (WGSN) in China.

Q&A
Thank you!