Access Network Technologies for Future Internet

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2010. 9

Outline

- Changes of Networking
- Access Network Technologies
  - Current
  - Coming: Sensor Networks, WMNs, DTN
  - Future ?
- Discussions

Changes of Networking

- Environment
  - Trusted => Untrusted
- Users
  - Researchers => Customers => Things
- Operators
  - Nonprofits => Commercial
- Usages
  - Host-oriented => Data-centric
- Connectivity
  - E2E IP => Intermittent Connection
- Application Architecture
  - Client-Server => P2P

New Networks and Services

- Home Networks
- PANs
- BANs
- CDN
- Sensor Networks
- Intelligent Things
- Context Aware Services
- Social Networks
- Smart Phone

What is a Access Network?

- **Existing World**
  - Customer Network, Access Network, Core Network (Hierarchical structure)
  - Accessed by residential user, customer organization, and mobile user
  - Access to central server, core network for delivery packet
- **Current and Coming World**
  - We do not know the structure since we are trying to design now.
  - Strict hierarchical structure will be getting weak because of P2P and CDN etc
  - Accessing user group will be expanded to include intelligent things.

Access Networks

- **Current Access Networks**
  - For home: ADSL,
  - For Organization: T1, T3
  - For mobile user: Wi-Fi, WiMAX, …

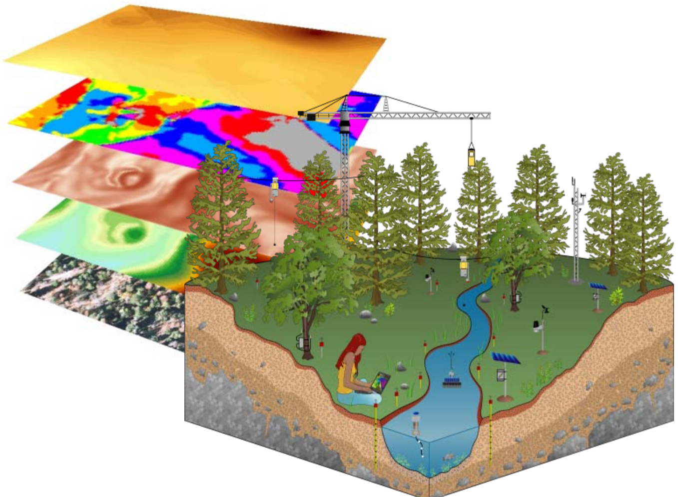
- **Coming Access Networks for Whom**
  - For Sensor Networks: …, DTN
  - For Intelligent things: WMN
  - For Mobile User: WMN

Characteristics for Future Customers/Networks

- Sensor Networks
  - Will be proliferated with wide usage such as environment monitoring, surveillance monitoring, bridge and building safety monitoring etc.
  - Most likely, they will have a sink node.
  - SpoVNet, Our Approach, IPUSN
- Internet of Intelligent Things (gadget)
  - Some of them are carried by human.
  - Some of them are fixed in the street or embedded such as appliances
  - Extending Reachability (WMN)
- Delay Tolerant Networks (DTN)
  - Heterogeneous Networks

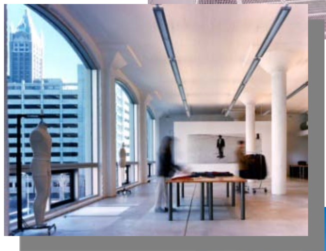
Sensor Network

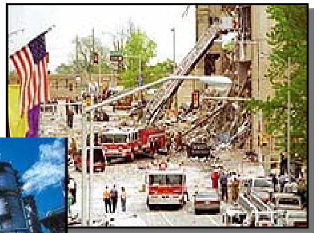
Why "Real" Information is so Important?



Save Resources

Improve Productivity





Enable New Knowledge

Increase Comfort

Enhance Safety & Security

Preventing Failures

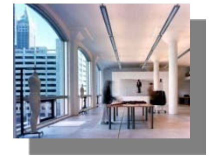
High-Confidence Transport

Improve Food & H20

Protect Health

WSN Applications

- Monitoring Spaces
  - Env. Monitoring, Conservation biology, ...
  - Precision agriculture,
  - built environment comfort & efficiency ...
  - alarms, security, surveillance, EPA, OSHA, treaty verification …
- Monitoring Things
  - automated meter reading
  - condition-based maintenance
  - disaster management
  - Civil infrastructure
- Interactions of Space and Things
  - manufacturing, asset tracking, fleet & franchise
  - context aware computing, non-verbal communication
  - Assistance - home/elder care
- Action and control
  - Optimizing processes
  - Automation

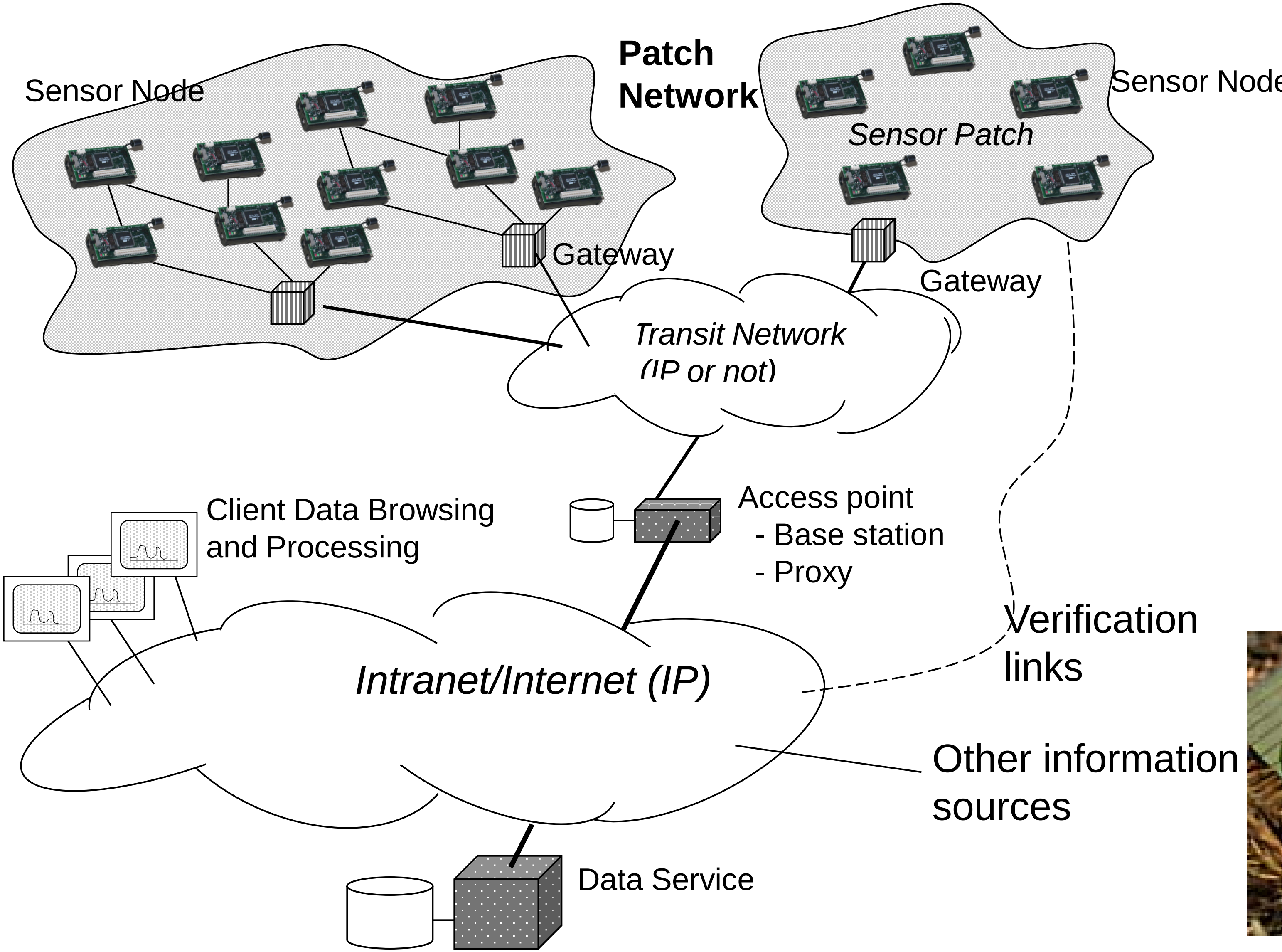


How to connect sensor networks

- IP/USN
- SpoVNet
- P2P Overlay

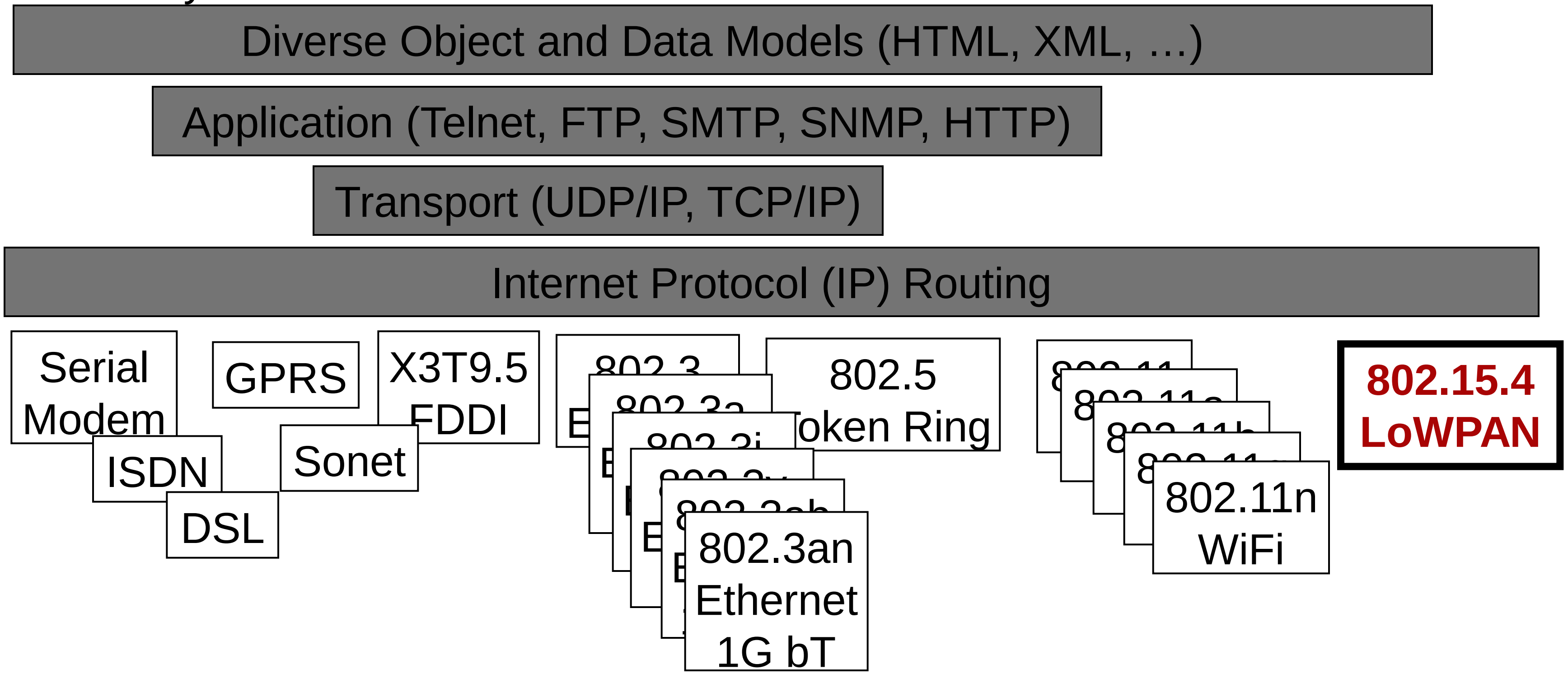
IP/USN

Canonical SensorNet Network Architecture



Lesson 1: IP

- Separate the logical communication of information from the physical links that carry the packets.
  - Naming
    - Hostname => IP address => Physical MAC
  - Routing
  - Security



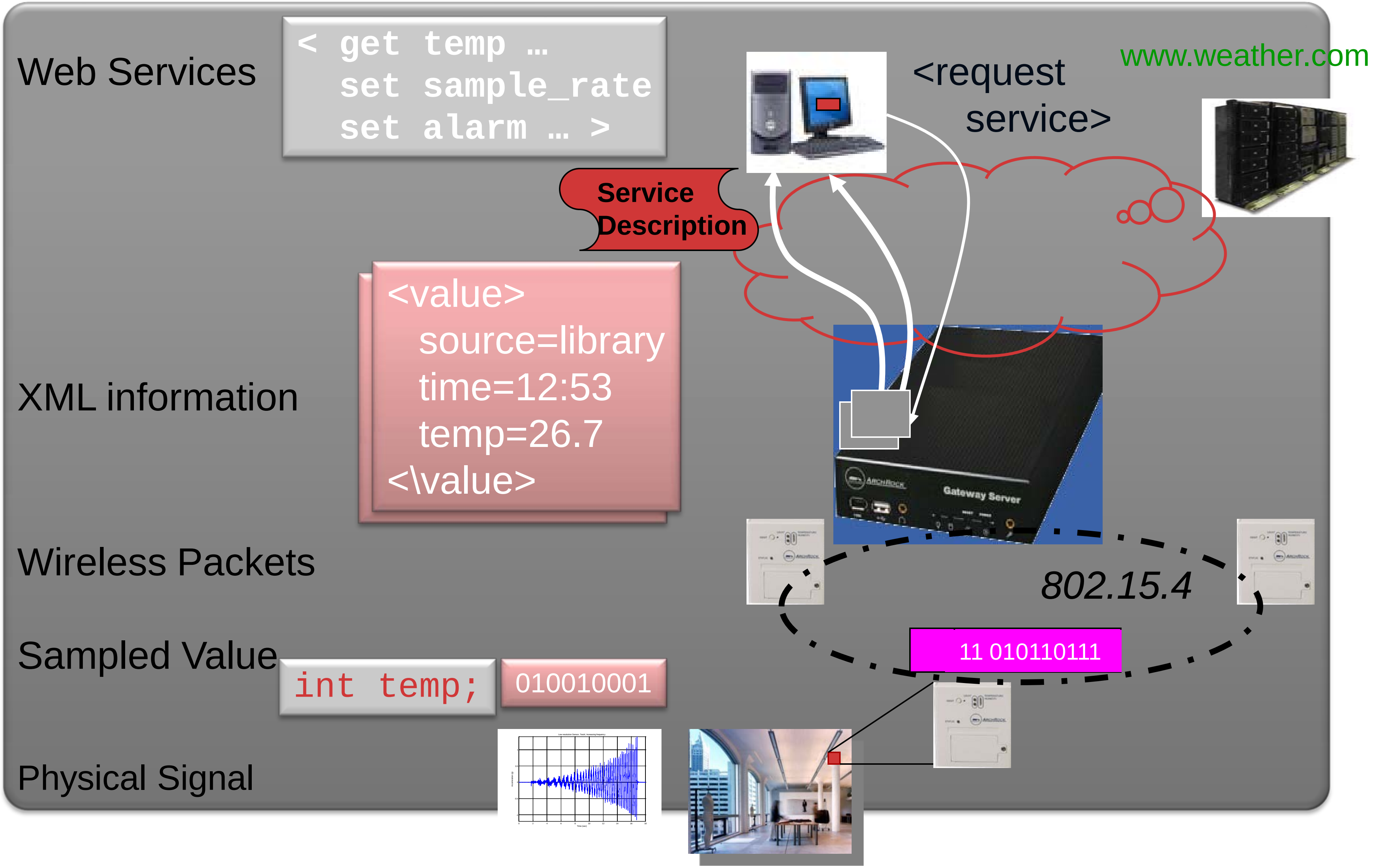
But, …

- isn’t IP too heavyweight for low-power, wireless, microcontroller based devices?

- No!

- 6lowpan compression with high quality multihop routing
  - Reliability and lifetime of the best mesh
  - Interoperability of IP

Our goal: Ubiquitous Real Internet



SpoVNet

- Spontaneous Virtual Networks
  - Connecting Sensor Network Islands to the Future Internet using the SpoVNet Architecture

Motivation/Objectives

- Heterogeneity of network technologies makes the controllability of complex, global communication systems difficult.
- SpoVNet follows the approach of providing spontaneous communication by composing algorithms and protocols that allow self-organization in distributed systems.
- Self-organizing systems are able to adapt to the given requirements and network loads flexibly, without further involvement of administrative expenditure.
- The main objective of spovnets is to provide the actual arising service needs spontaneously, autonomously and adaptively

Cargo Tracking System

- Today’s Cargo tracking system

  - Consist of GPS receiver and a mobile phone unit
  - Attached to the actual cargo container
  - allows tracking of container locations

- Online monitoring tracking system

  - The GSM unit in current location tracking systems is not limited to the transfer of GPS coordinates
  - To reduce costly GSM communication, Several containers can use a single GSM unit that is attached to a dedicated container.
  - Cost and availability of GSM communication is still problematic and only allows transmission of data at large intervals

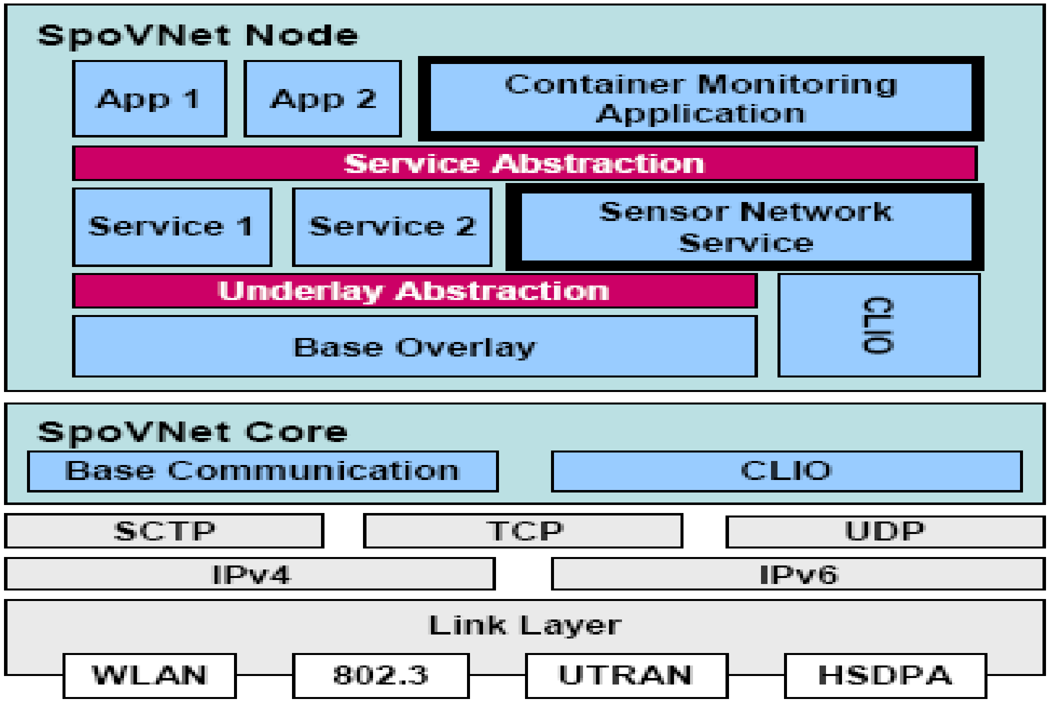
Cargo Tracking System

- However, It is not satisfying

  - No continuous connectivity is available, therefore disallowing online monitoring
  - Communication is costly, making monitoring expensive

- So, we employ a new Container Monitoring Application (CMA) on top of SpoVNet that uses SNS to access sensor network islands and perform the actual communication for our monitoring application.

SpoVNet



Sensor Network Service and Container Monitoring Application in the SpoVNet Architecture

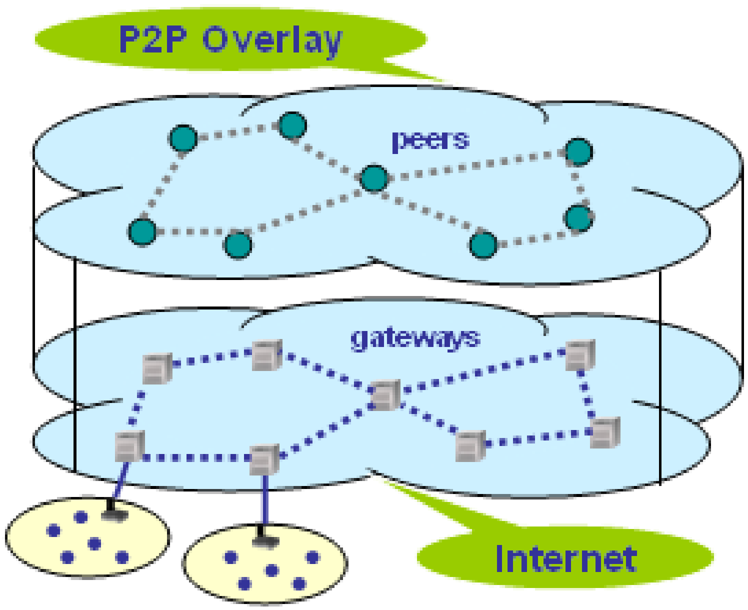
P2P Overlay Network for Sensor Network

Using P2P Service Concept

- Peer-to-Peer Technology
  - Significant autonomy from central servers
  - Exploits resources at the edges of the Internet
    - Storage and contents
    - Computing power
    - Connectivity and presence
- P2P Service Scenario
  - The nodes in P2P networks function as both clients and servers to the other nodes on the network
  - A peer node finds other peer nodes which have information it wants
  - All content is transferred directly between peer nodes without passing through third party servers.

P2P Approach to USN Integration

- Adopting P2P techniques, each USN with a gateway act as a peer
- The main goal of P2P overlay is to treat the underlying heterogeneou s USNs as a single unified network, in which users can send queries without considering the details of the network
- User peers communicate with gateway peers in a P2P approach

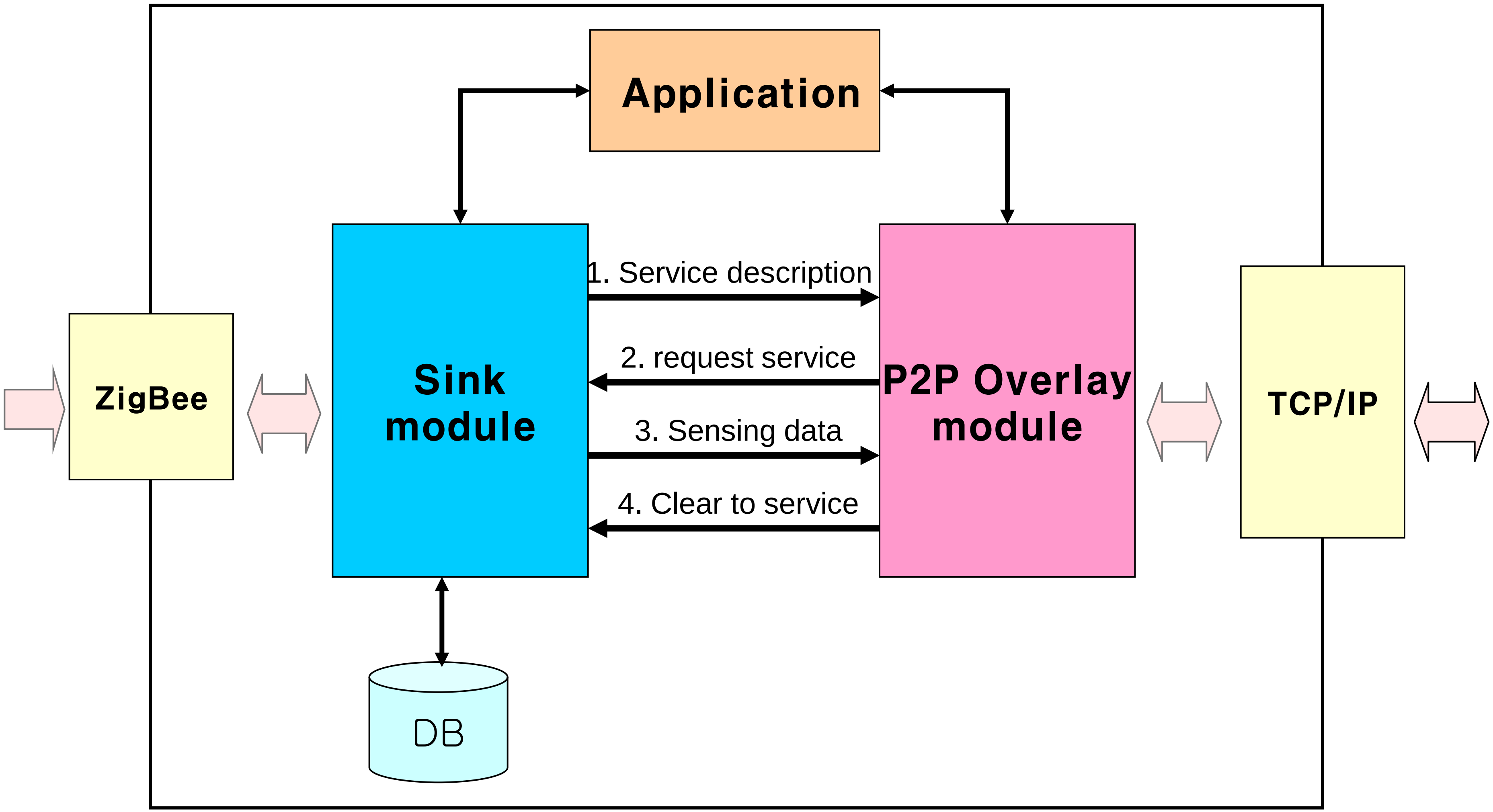


[Lei Shu, SAINT 2008]

P2P USN Approach

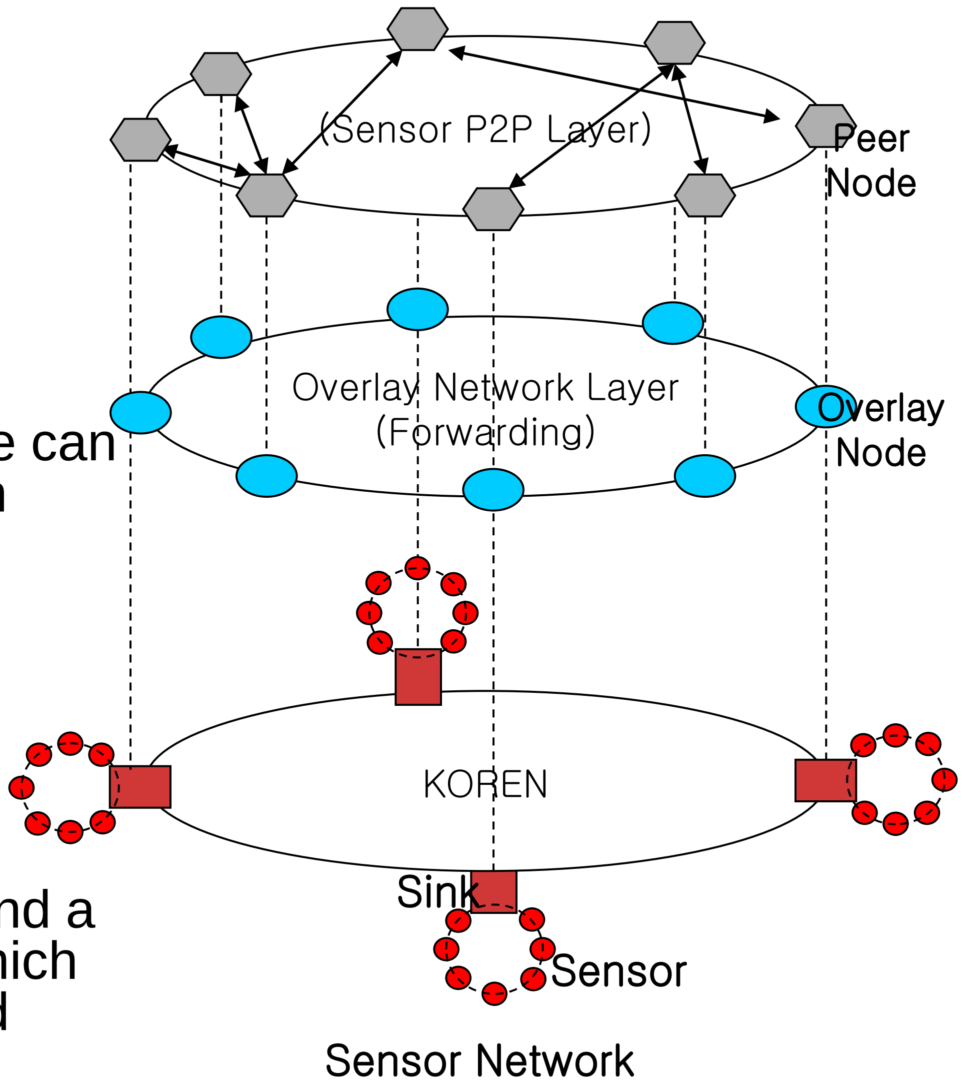
- General P2P overlay network for USN Service
  - If a P2P peer software is installed in sink nodes, sensor nodes, and users, all USNs can be shared by users and other USNs.
  - USN application service is possible without its specific USNs
- Service Scenarios
  - A peer node (user) can find sensor networks which can provide sensor information it wants.
  - A USN can find other USN for collaboration
  - A USN can find a peer node (user) which needs its sensory information
- Advantages
  - Share already deployed sensor networks and need not deploy new sensor networks for specific USN service.
  - Exploit various information of USNs
  - P2P USN becomes an infrastructure for general service providers

Sink Node Architecture

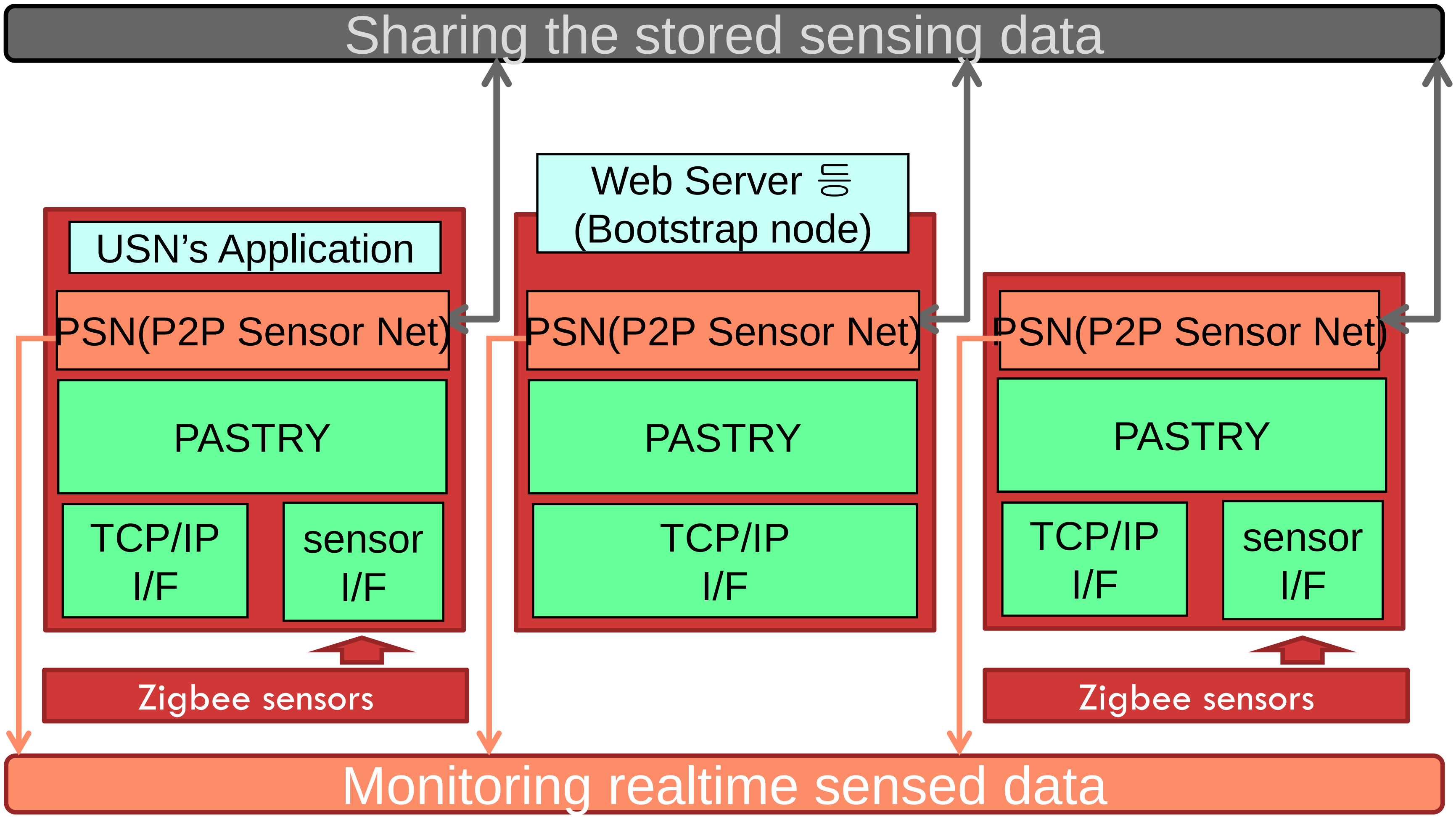


Sensor P2P Service for Sharing USNs

- P2P USN
  - finding service providers, service users, corresponding nodes
  - forwarding information through multicast tree
- P2P USN Service Scenario
  - USN's sink node or a sensor node can be a P2P node and advertize own services / information.
  - a P2P node can also advertize services / information it wants.
  - a P2P node can find a service / information it wants and ask it to peer node.
  - a sink node or sensor node can find a peer node (user or other USN) which wants its service / information and provide that.

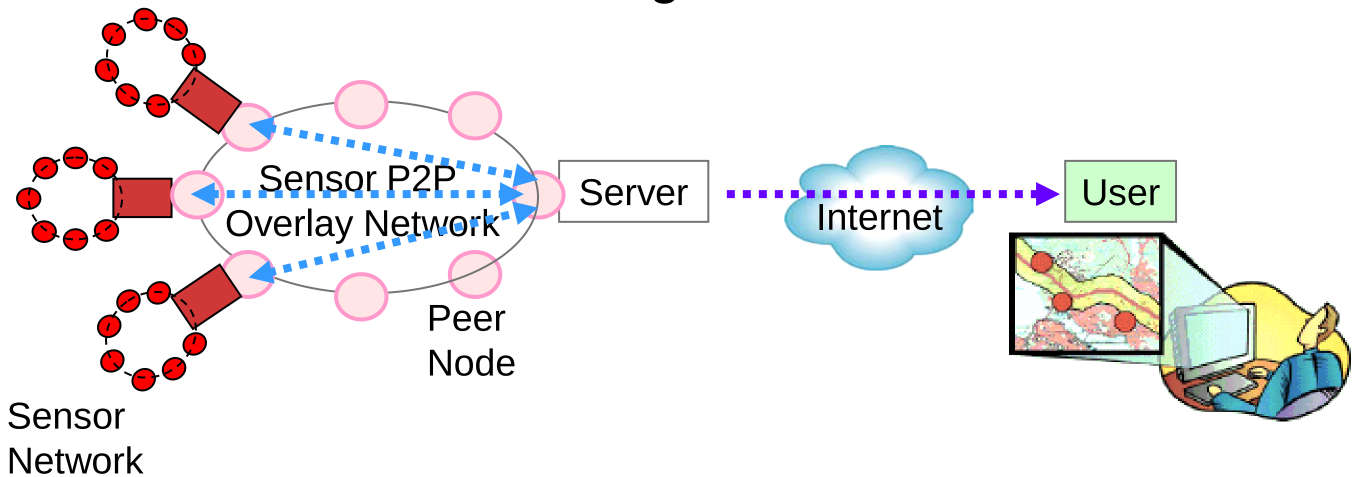


Peer Node's Architecture

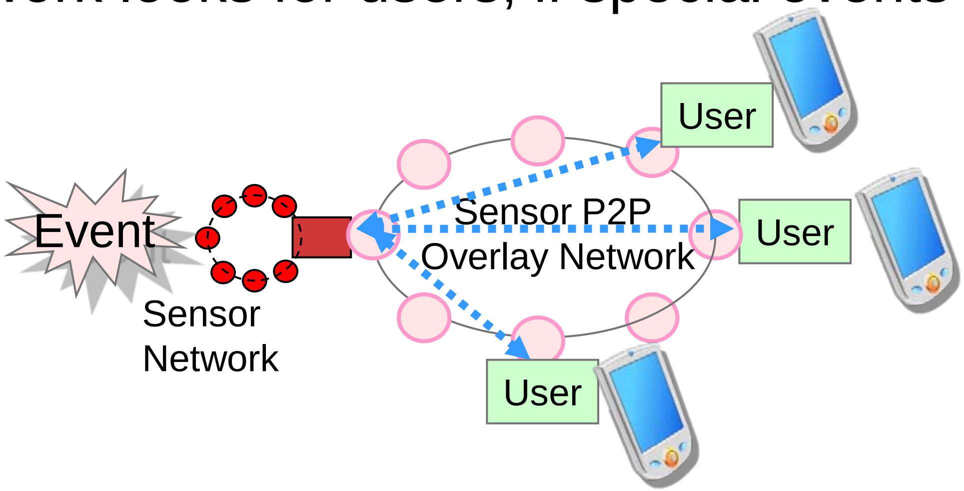


P2P USN Service Scenarios

- An Application server finds and gathers information.



- Sensor network looks for users, if special events happen



Towards an Internet of Things: Requirements, Challenges and Initial Solutions

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Background of the Internet of Things

RFID-based "Internet of Things", Auto-ID Lab, MIT, 1999

→ GS1 EPC Global: identification, service infrastructure

Focus: passive identification of things, integration into an infrastructure

Things(Wireless) Sensor & Actuator Networks

Focus: sensing of real-world information, possibly large scale like habitat monitoring, military applications

Smart Objects/ Cooperating Objects
(e.g., EU SmartIts, CoBIS projects)

Focus: communicating objects, functionality in the objects themselves

Internet of Things

IoT Definition

- In computing, the **Internet of Things** refers to **a network of objects**, such as household appliances. It is often a **self-configuring wireless network**. The concept of the *internet of things* is attributed to the original Auto-ID Center, founded in 1999 and based at the time in MIT [Wikipedia].

- **Internet of Things** (IoT) is an integrated part of Future Internet and could be defined as a ***dynamic global network infrastructure with self configuring capabilities based on standard and interoperable communication protocols*** where physical and virtual “things” have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network [Strategic Research Agenda EU CERP-IoT Cluster].

Enabling Trends for the Internet of Things

- Moore's law: decreasing hardware costs
- Hundreds of micro-controllers in every home
- New products (Nabaztag) & services (stickybits)
- Simplified embedded development (SunSpot)
- Accelerated proliferation of networked devices
  - video cameras, public displays, cars
- Maturity and ubiquitous availability of enabling technologies, e.g.
  - tagging technologies (RFID, barcodes, WSN)
  - augmented reality and video analysis
  - context processing

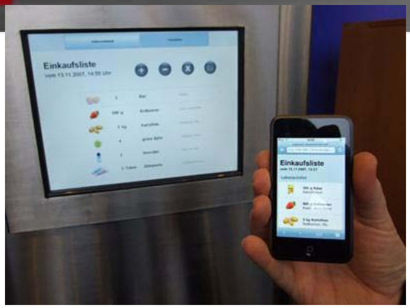
→ **Networked Things become ubiquitous**

Nabaztag Rabbit

Source: metaio

Brick
(with an RFID)

II.5 Example Scenarios



Intelligent fridge → helps generating shopping list

Automatic tracking of selected Things
→ simplified checkout
□and payment

Product history
→ check storage conditions, carbon footprint

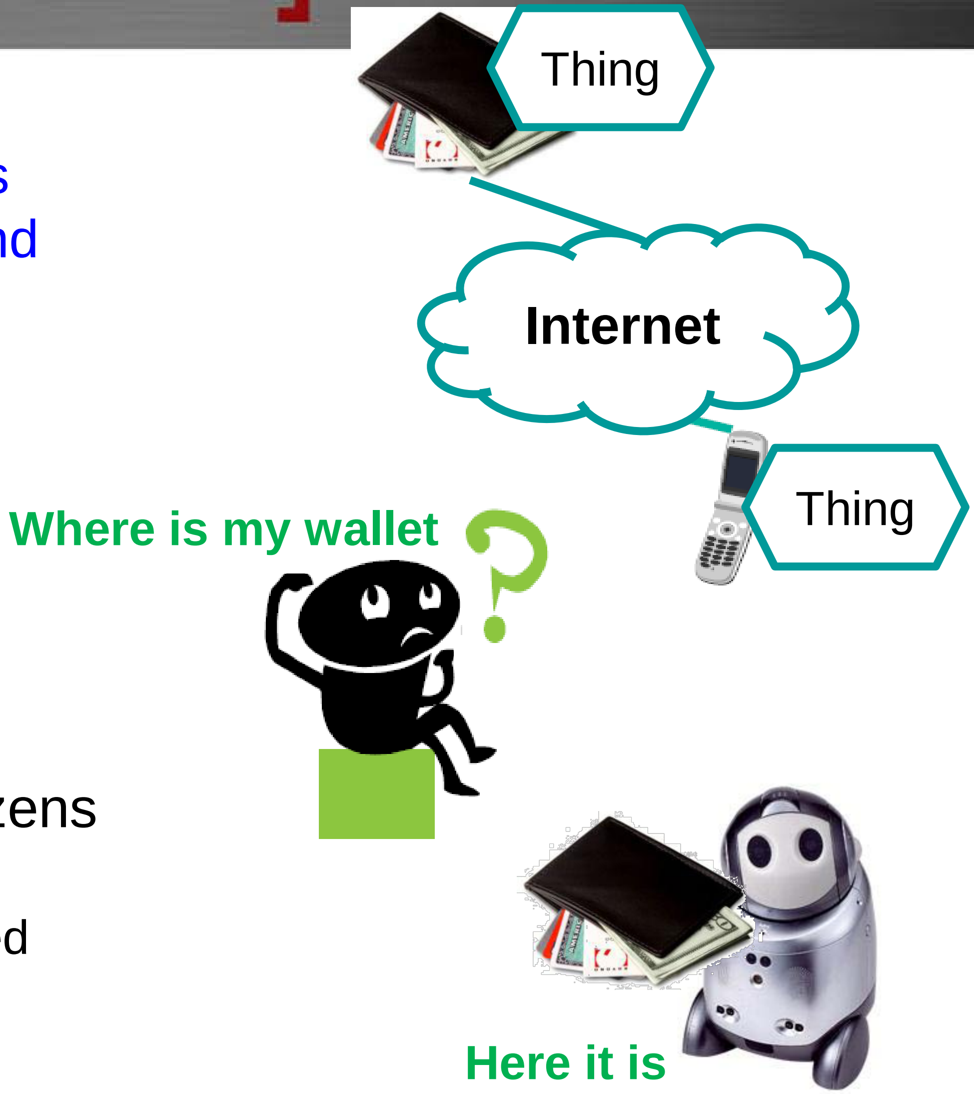
Support correct delivery

Warning of incompatible chemicals

Selecting clothes with support from girl friend @ home

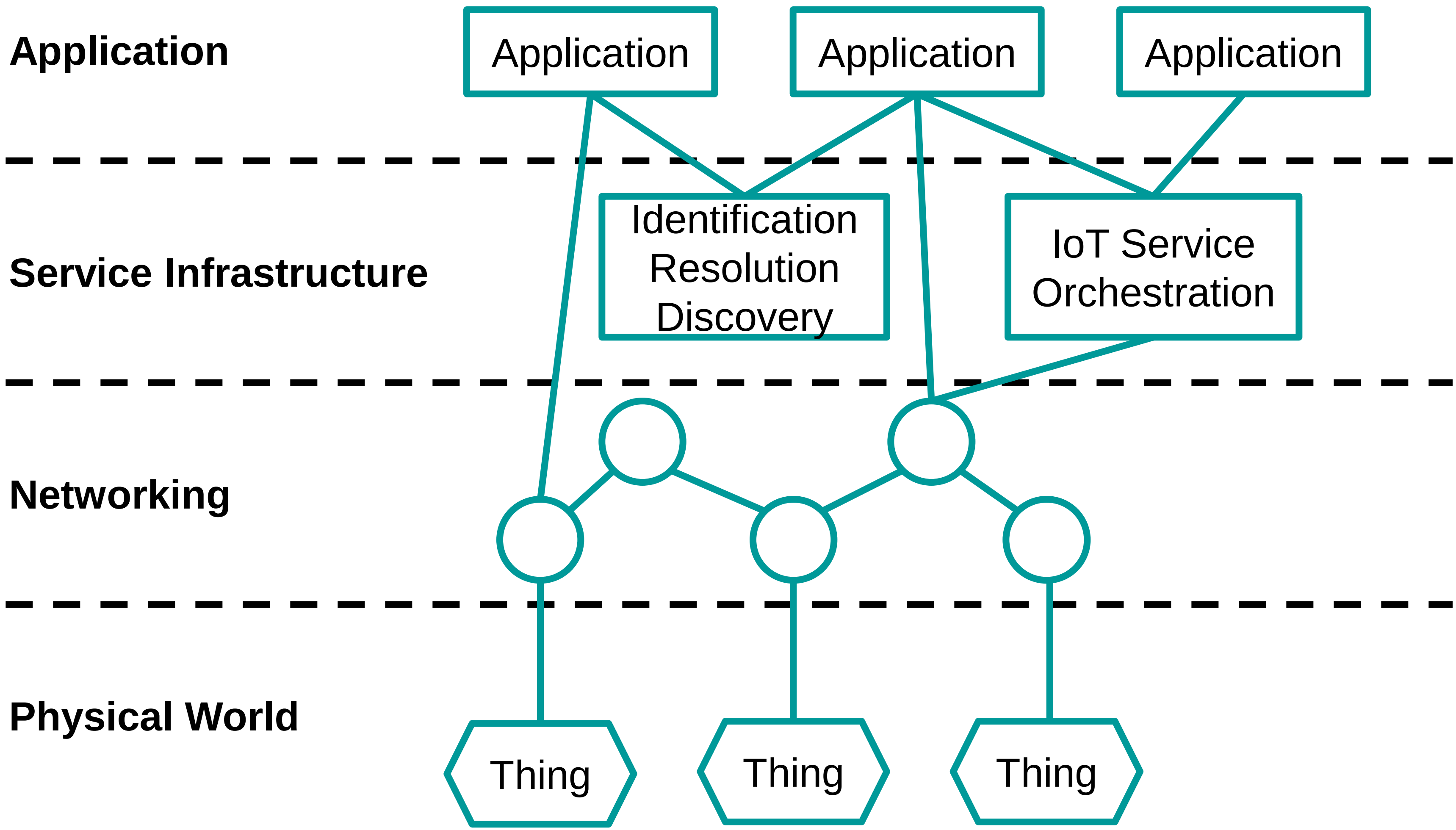
IoT Requirements

- Things need to be identified
- Things get attached to networks
- Things have to communciate and federate
- Things need to be discoverable
- Things can interact with users



→ Things become first class citizens of the Internet of Services
  - Provide services that can be called
  - Provide service frontends

IoT Conceptual Layers



SENSEI -Targets

- One of the FP7 Call 1 Future Internet Flagship projects
- 1/2008 – 12/2010 – 19 partners - ~ 23M€ Project Volume
- **Project Objectives**
  - A **highly scalable architectural framework** with corresponding protocol solutions that enable easy plug and play integration of distributed WS&AN into a global system –supporting network and information management, security, privacy, trust and accounting.
  - **Open service interfaces** and corresponding semantic specification to unify the access to context information and actuation services.
  - Efficient **WS&AN island solutions** consisting of a set of cross-optimised and energy aware protocol stacks
  - Pan European test platform, enabling large scale experimental evaluation of the SENSEI results and execution of field trials – a tool for evaluation of WS&AN integration into the Future Internet.

Scenario Overview

SENSEI project is targeting a wide range of scenarios that have been used for requirement analysis and will be used as a basis for evaluation

- Audio-visual showcases of Scenarios
  http://www.ict-sensei.org/Sensei_090422/

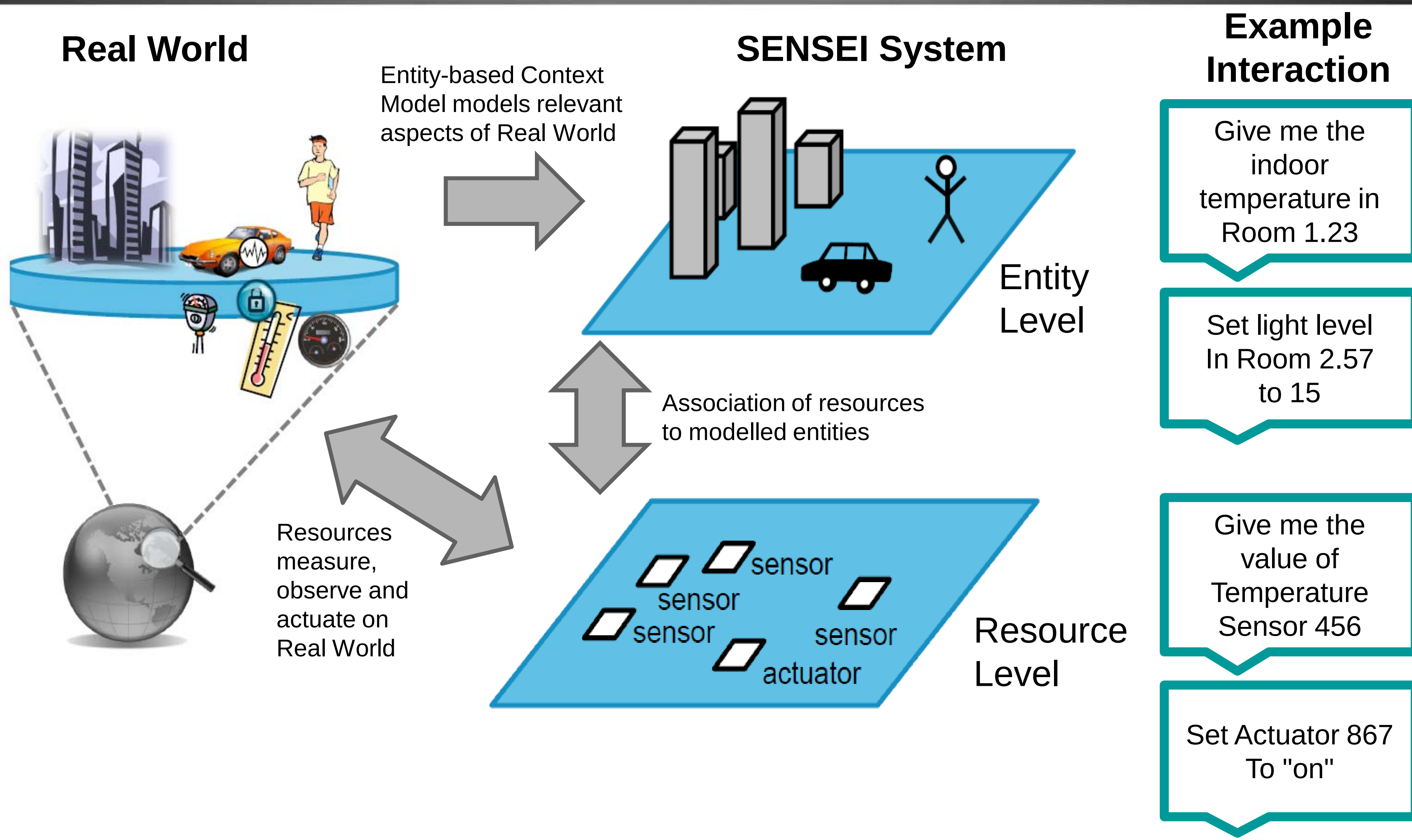
- Multimodal Traveller
  Worker in a Plant
  Smart Places
  Crisis Management

IV.4 Crisis Management Scenario (1)

IV.5 Crisis Management Scenario (2)

In the stadium, SENSEI makes use of deployed fixed and wireless sensor and actuator networks. Various systems are actuated to support the evacuation: Emergency exits are opened, signage is updated, sprinklers are activated if necessary. Mobile sensors carried by the staff and emergency personnel are recognised and integrated into the crisis application.

SENSEI Modelling and Interactions



SENSEI Goals and Relation to IoT

- **SENSEI focuses on integration of Wireless Sensor and Actuator Networks**(WS&AN), not RFID or smart objects
- SENSEI resources **provide sensor/context information** or execution of specific actuation tasks**, not general business processes** and workflows
- SENSEI integrates **heterogeneous technology** in sensor networks **through resource concept and gateways**
- SENSEI architecture targets large scale
- SENSEI offers **two abstraction layers** for interacting with the real world: resource level and entity level

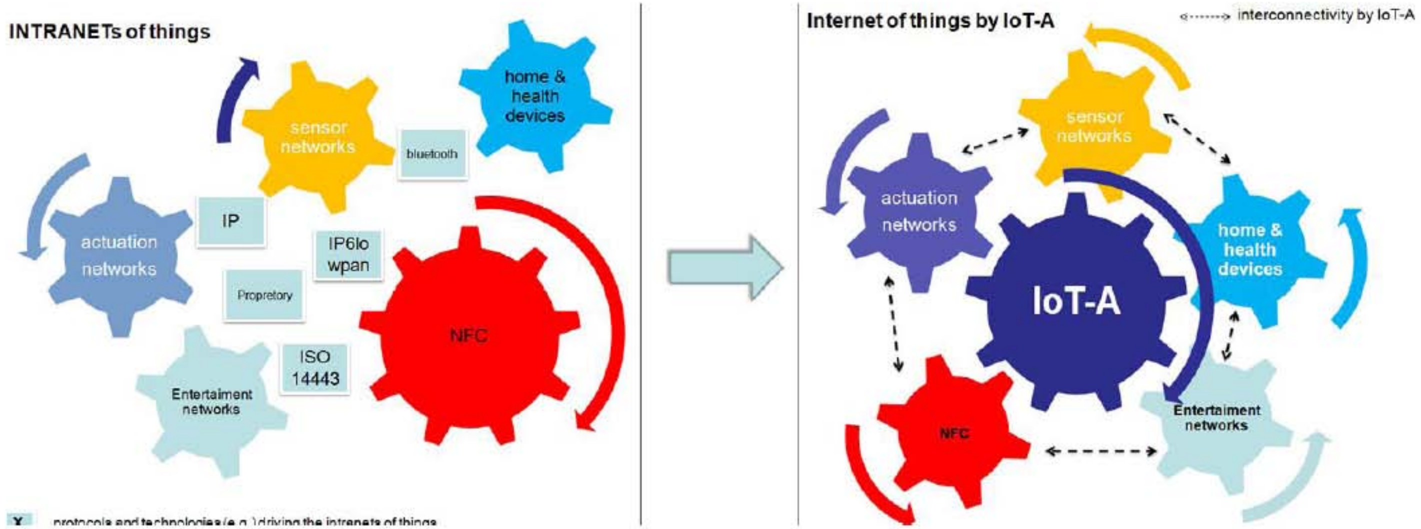
→ SENSEI provides a large scale **IoT infrastructure that is focused on retrieving information and** executing **actuation** tasks

→ Introduces **concepts** that may be **extensible** to cover broader range of **general IoT** scenarios

IoT-A: Internet of Things Architecture

- **Current IoT status**
  - - **Fragmented architectures**, no coherent unifying concepts, solutions exist only for application silos
  - - **No holistic approach** to implement the IoT has been proposed, yet
  - - Many **island solutions** do exist (RFID, Sensor networks, etc.)
  - - In essence, there are only **Intranets of Things** existing

- **Achieve an Internet of Things**



FP7 IoT-A

- **Goals**
  - - **Architectural reference model** for the interoperability of Internet-of-Things systems
  - - **Mechanism for efficient integration into the service layer** of the Future Internet
  - - **Resolution infrastructure**, allowing **scalable lookup and discovery** of Things
  - - Novel platform components
  - - Implementation of real-life use cases demonstrating the benefits of the developed architecture
- **Approach**
  - - Integrate existing efforts into a **unified architecture**
  - - Design **open interfaces**
  - - Develop **bridges connecting different technologies** from the hardware to the service layer

Characteristics of IoT

- **Heterogeneity of technologies** (devices, networks)
- **Interconnection of billions/trillions of object**s in the real-world which can be electronically identified and/or communicate
- Accurate reflection of real world allowing **near real-time interaction**
- **Physical aspects like location, direction, proximity** will be used for identifying target objects
- All kind of machines will work on the provided information□ → clear specification of semantics needed
- **Let's look at some concrete challenges …**

Selected Challenges

- Interconnection of heterogeneous IoT technologies
- Suitable abstraction levels for application interfaces
- Unified identification, resolution and discovery of Things
- Orchestrating IoT services in a scalable way
- ... many more ...

Conclusion and Summary

Enabling technologies for Internet of Things already maturing

- Integrated computing devices with communication capabilities
- Processing technologies, e.g. data fusion and classification, inference/reasoning
- Business process modelling and semantic technologies

Key is to combine these technologies into a homogeneous fabric for the Internet of Things

Challenges and Approaches

- Interconnection of heterogeneous IoT technologies □common abstraction: *resource*
- Suitable abstraction levels for application interfaces □allow entity-and resource level interaction
- Unified identification, resolution and discovery of Things □two-level lookup with dynamic associations between entities and resources
- Orchestrating IoT services in a scalable way □mapping parts of business processes onto things themselves

WMN: Wireless Mesh Network

Overview

Node Types

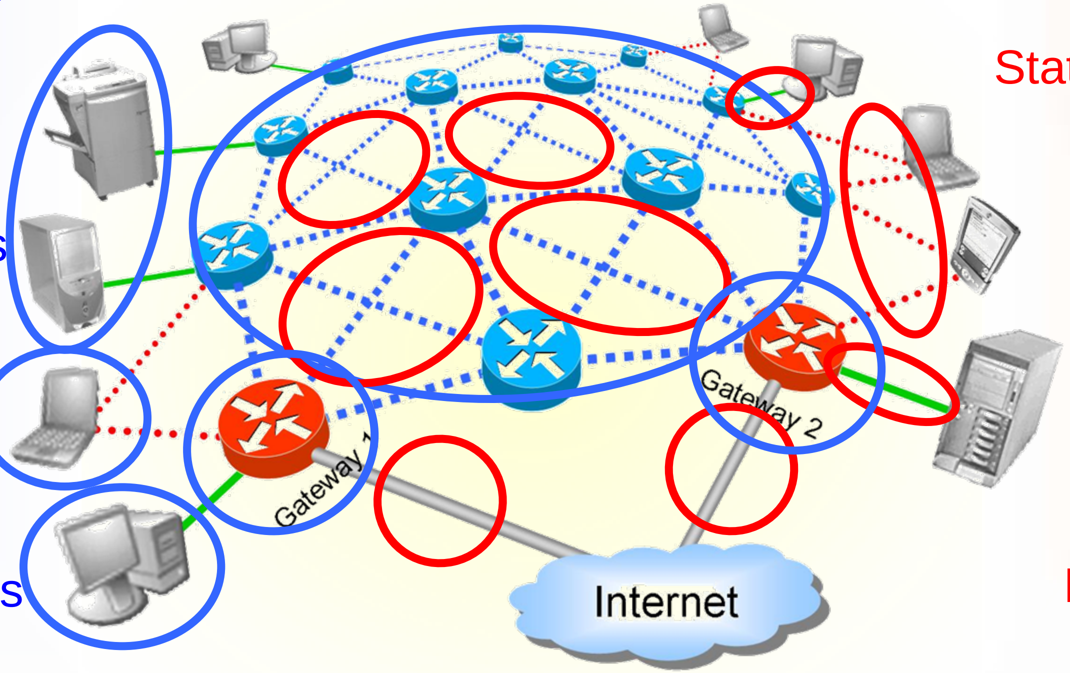
Wireless routers

Gateways

Printers, servers

Mobile clients

Stationary clients



Link Types

Intra-mesh wireless links

Stationary client access

Mobile client access

Internet access links

Mesh vs. Ad-Hoc Networks

Ad-Hoc Networks

- Multihop
- Nodes are wireless, possibly mobile
- May rely on infrastructure
- Most traffic is user-to-user

Wireless Mesh Networks

- Multihop
- Nodes are wireless, some mobile, some fixed
- It relies on infrastructure
- Most traffic is user-to-gateway

Mesh vs. Sensor Networks

Wireless Sensor Networks

- Bandwidth is limited (tens of kbps)
- In most applications, fixed nodes
- Energy efficiency is an issue
- Resource constrained
- Most traffic is user-to-gateway

Wireless Mesh Networks

- Bandwidth is generous (>1Mbps)
- Some nodes mobile, some fixed
- Normally not energy limited
- Resources are not an issue
- Most traffic is user-to-gateway

Wireless Access Network Selection for Live Streaming Multicast in Future Internet

Jaecheol Kim, Yanghee Choi of SNU, Korea

Introduction

- Recently, IP multicast is revisited because many applica -tions are emerging which need the support of multicast. Heterogeneity of radio access networks will be also prevalent in future Internet and almost every mobile host will have multiple radio interfaces, which will pose any challenges on how to select the most appropriate access network in terms of user satisfaction and system resource efficiency.

Proposed Scheme

- Our goal is to devise an optimal wireless access network selection scheme for live streaming multicast services to maximize user satisfaction and system profit at the same time.
- User satisfactory level is directly impacted by available bandwidth and handoff delay.

Proposed Scheme

- The degree of satisfaction of bandwidth requirement is given by the bandwidth utility function as follows, where K is constant (0.62086) and b is bandwidth.

$$U(b) = 1 - e^{-\frac{b^2}{K+b}}$$

Proposed Scheme

- Another factor of user satisfaction is dependent on handoff latency caused by user's mobility.
- Service degradation function is given as follows t_h equation, where σ is a constant (8.37) that has a larger value for non-real time applications and smaller value for real time applications.

$$S_d(t_h) = e^{\frac{t_h^2}{2\sigma^2}}$$

Proposed Scheme

- We combine the above two functions into a single value to quantify user satisfaction and we will use this value as the criteria for access network selection. In following equation, t_{iH} is $i-t_h$ horizontal handoff delay and t_V is vertical handoff delay.

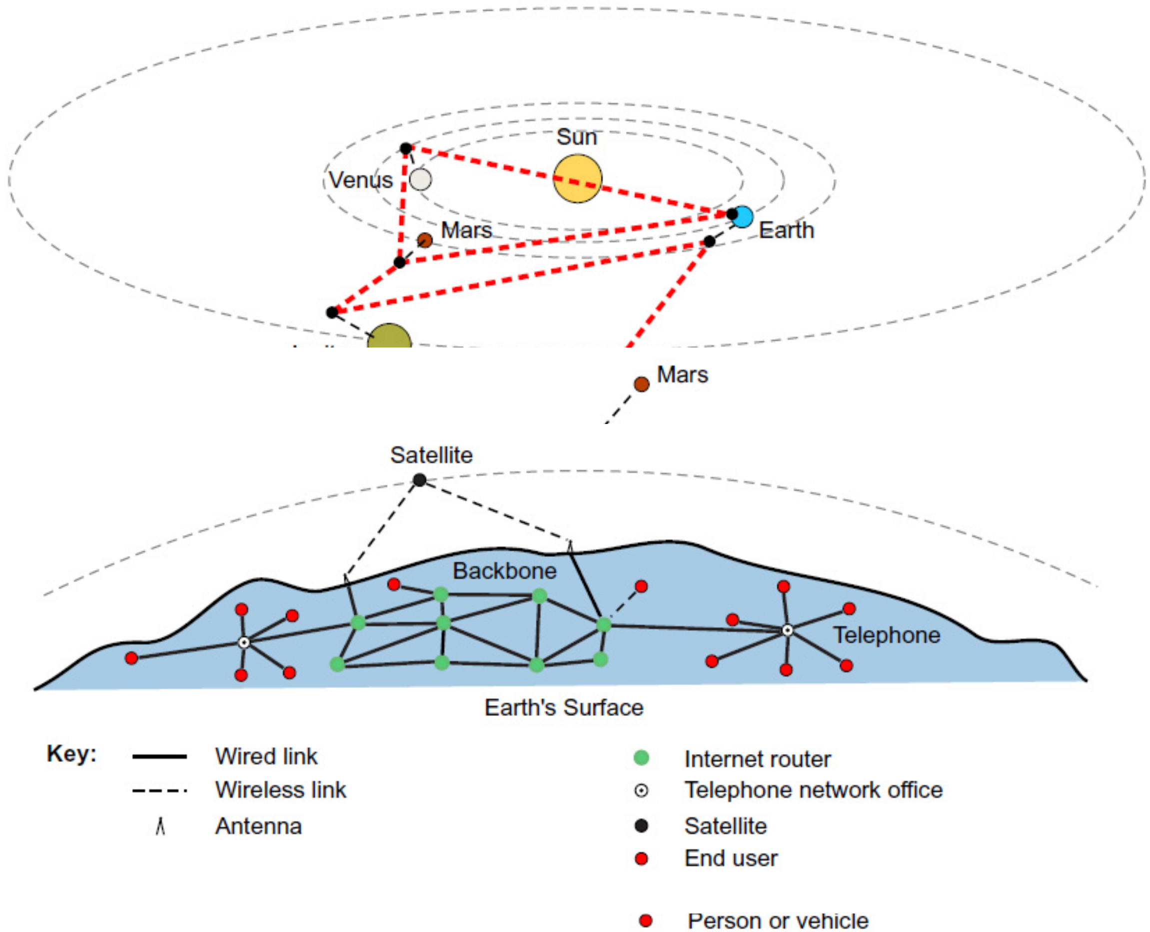
$$S = \begin{cases} U(b) \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \mathit{normal\_service} \\ U(b) \times \prod_{i=1}^{n} S_d(t_{iH}) \cdots\cdots\cdots\cdots\cdots \mathit{horizontal\_handoff} \\ U(b) \times S_d(t_V) \times \prod_{i=1}^{n-1} S_d(t_{iH}) \cdots\cdots \mathit{vertical\_handoff} \end{cases}$$

Future Internet Access Network Technologies: Delay Tolerant Network

Motivation

- Evolve wireless networks outside the Internet
  - Problems with inter-networks having operational and performance characteristics that make conventional networking approaches either unworkable or impractical.
  - Accommodate the mobility and limited power if future wireless devices
- Examples of wireless networks outside of the Internet:
  - Terrestrial civilian networks connecting mobile wireless devices including personal communicators, intelligent highway and remote Earth outposts.
  - Wireless military battlefield networks connecting troops, aircraft, satellites and sensors (on land or water)
  - Outer-space networks, such as the "**Interplanetary communications".**

Internet Evolving Concept

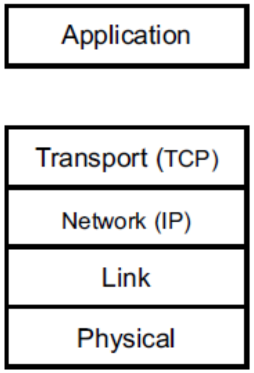


Why DTNs?

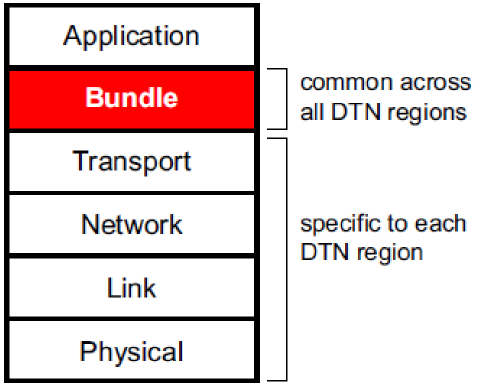
- Current Internet was designed for
  - Continuous, bidirectional end-to-end path
  - Short round-trips
  - Symmetric data rates
  - Low error rates
- Many evolving and challenged networks do not confirm to the current Internet's philosophy
  - Intermittent connectivity
  - Long or variable Delay
  - Asymmetric data rates
  - High error rates

DTN Concept

- Build upon the extended "bundling" architecture (an end-to-end message-oriented overlay)
  - Proposes and alternative to the Internet TCP/IP end-to-end model.
  - Employs hop-by-hop storage and retransmission as a transport-layer overlay.
  - Provides messaging service interface (similar to electronic mail)
- The wireless DTN technologies may be diverse
  - E.g.: RF, UWB, free-space optical, acoustic (solar or ultrasonic) technologies …

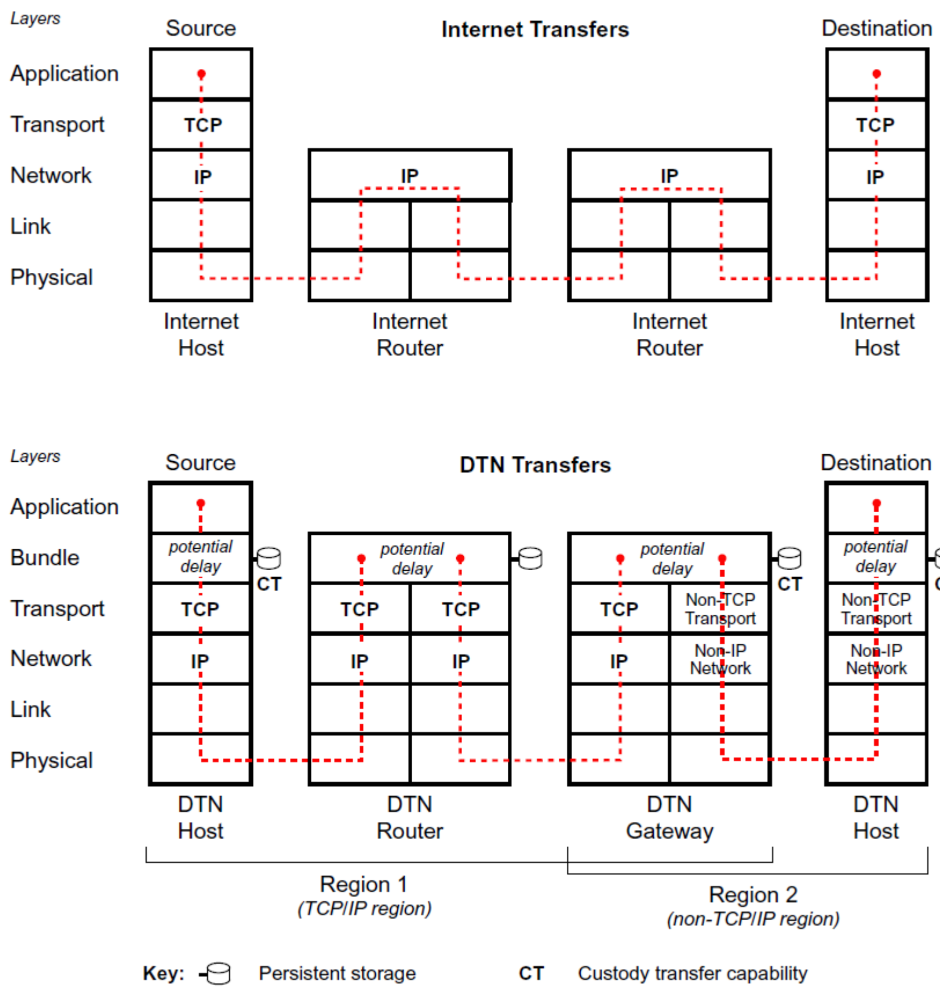


Internet Layers



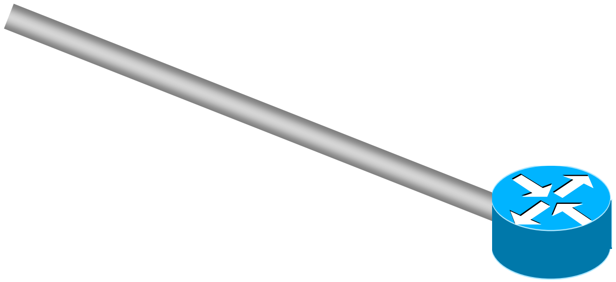
DTN Layers

Current Internet vs. DTN Routing



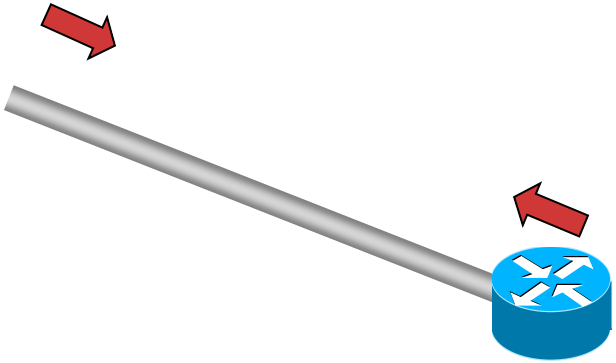
Types of DTN contacts

- Persistent contacts



Types of DTN contacts

- Persistent contacts
- On-demand contacts



- Persistent contacts
- On-demand contacts
- Intermittent – scheduled contacts (predicted contact)