Access Network Technologies for Future Internet

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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?

- Improve Productivity
- Save Resources
- Preventing Failures
- Enable New Knowledge
- Increase Comfort
- Enhance Safety & Security
- Improve Food & H2O
- Protect Health
- High-Confidence Transport
- Enable New Knowledge
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
Canonical SensorNet
Network Architecture

Intranet/Internet (IP)

Access point
- Base station
- Proxy

Verification links

Other information sources

Client Data Browsing and Processing

Data Service
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

Diverse Object and Data Models (HTML, XML, …)
Application (Telnet, FTP, SMTP, SNMP, HTTP)
Transport (UDP/IP, TCP/IP)

Internet Protocol (IP) Routing

- Serial Modem
- GPRS
- X3T9.5
- ISDN
- Sonet
- DSL
- 802.3
- 802.3i
- 802.3y
- 802.3a
- 802.3ab
- 802.3an
- Ethernet
- 1G bT
- 802.5
- Token Ring
- 802.11
- Wi-Fi
- 802.15.4
- LoWPAN
- 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

Web Services

<value
source=library
time=12:31
temp=25.1
</value>

XML information

<value>
source=library
time=12:53
temp=26.7
</value>

Wireless Packets

Sampled Value

int temp; 010010001

Physical Signal

Physical Signal

Service Description

<request
service>

<internal_command>
get temp ...
set sample_rate
set alarm ...
</internal_command>

Web Services

www.weather.com

802.15.4

Physical Signal

Low resolution Sensor, Test4, Increasing frequency

Time (sec)

Acceleration (g)
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.
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
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.
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 heterogeneous 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

1. Service description
2. request service
3. Sensing data
4. Clear to service
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 advertise own services / information.
  - a P2P node can also advertise 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.
Sharing the stored sensing data

- **USN's Application**
  - PSN (P2P Sensor Net)
    - PASTRY
      - TCP/IP I/F
      - sensor I/F
      - Zigbee sensors

- **Web Server**
  - (Bootstrap node)

- **PSN (P2P Sensor Net)**
  - PASTRY
    - TCP/IP I/F

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    - sensor I/F
    - Zigbee sensors

**Monitoring realtime sensed data**
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
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
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 *communicate 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

Application
- Application
- Application
- Application

Service Infrastructure
- Identification Resolution Discovery
- IoT Service Orchestration

Networking

Physical World
- Thing
- Thing
- Thing
SENSEI - Targets

- One of the FP7 Call 1 Future Internet Flagship projects


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.
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

- Multimodal Traveller
- Worker in a Plant
- Smart Places
- Crisis Management
During the games, smoke is sensed in the stadium and in the surrounding area. The smoke also affects the mall nearby. As soon as the incident is sensed, the risk is modelled, the threat level is assessed and an evacuation is prepared.
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

Real World

Entity-based Context Model: models relevant aspects of Real World

Resources measure, observe and actuate on Real World

SENSEI System

Association of resources to modelled entities

Entity Level

Resource Level

Example Interaction

Give me the indoor temperature in Room 1.23
Set light level in Room 2.57 to 15
Give me the value of Temperature Sensor 456
Set Actuator 867 to "on"
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**
● 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 objects** 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 ...
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
Recently, IP multicast is revisited because many applications 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.
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.

\[
U(b) = 1 - e^{-\frac{b^2}{K + b}}
\]
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 $\sigma$ is a constant (8.37) that has a larger value for non-real time applications and smaller value for real time applications.

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

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

Key:
- Wired link
- Wireless link
- Antenna
- Internet router
- Telephone network office
- Satellite
- End user
- Person or vehicle
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 …
Current Internet vs. DTN Routing

Internet Transfers

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<th>Layers</th>
<th>Source</th>
<th>Internet Transfers</th>
<th>Destination</th>
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<tr>
<td>Physical</td>
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DTN Transfers

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<th>Layers</th>
<th>Source</th>
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<td>Transport</td>
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<td>TCP</td>
<td>DTN Gateway</td>
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<tr>
<td>Network</td>
<td>Non-IP Transport</td>
<td>Non-IP Transport</td>
<td>DTN Host</td>
</tr>
<tr>
<td>Link</td>
<td>Non-IP Network</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical</td>
<td>DTN Host</td>
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</table>

Key:
- Persistent storage
- CT Custody transfer capability
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)