# 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

# New Networks and Services

- Home Networks
- PANs
- BANs
- Sensor Networks
- Intelligent Things
- Context Aware Services

# Access Networks

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

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

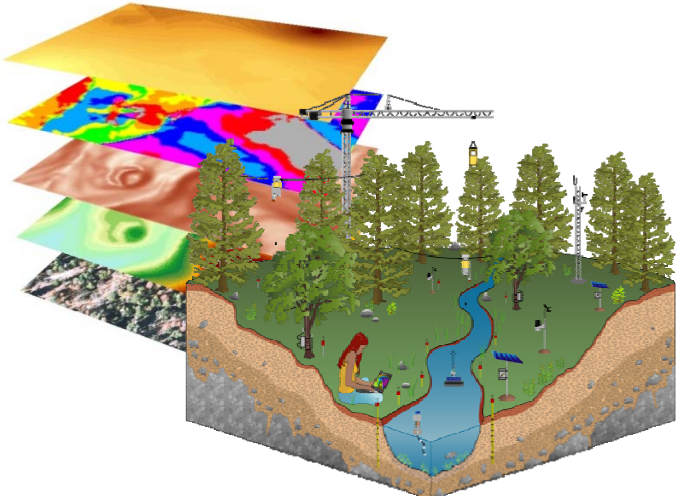
# Characteristics for Future Customers/Networks

- Sensor Networks
  - Will be scattered thru wilderness.
  - Most likely, they will have sink node.
  - SpoVNet, Our Approach, IPUSN
- Extending Reachability (WMN)
  - Intelligent Things (gadget)
  - Some of them are carried by human.
  - Some of them are fixed in the street or things such as appliances
- Delay Tolerant Networks (DTN)
  - Heterogeneous Networks

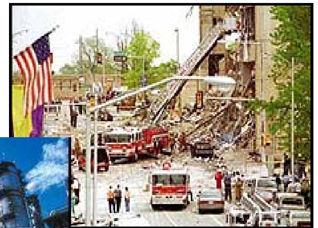
# Sensor Network

# Why “Real” Information is so Important?

Save Resources



Improve Productivity



Enable New Knowledge

Increase Comfort

Enhance Safety & Security

Preventing Failures

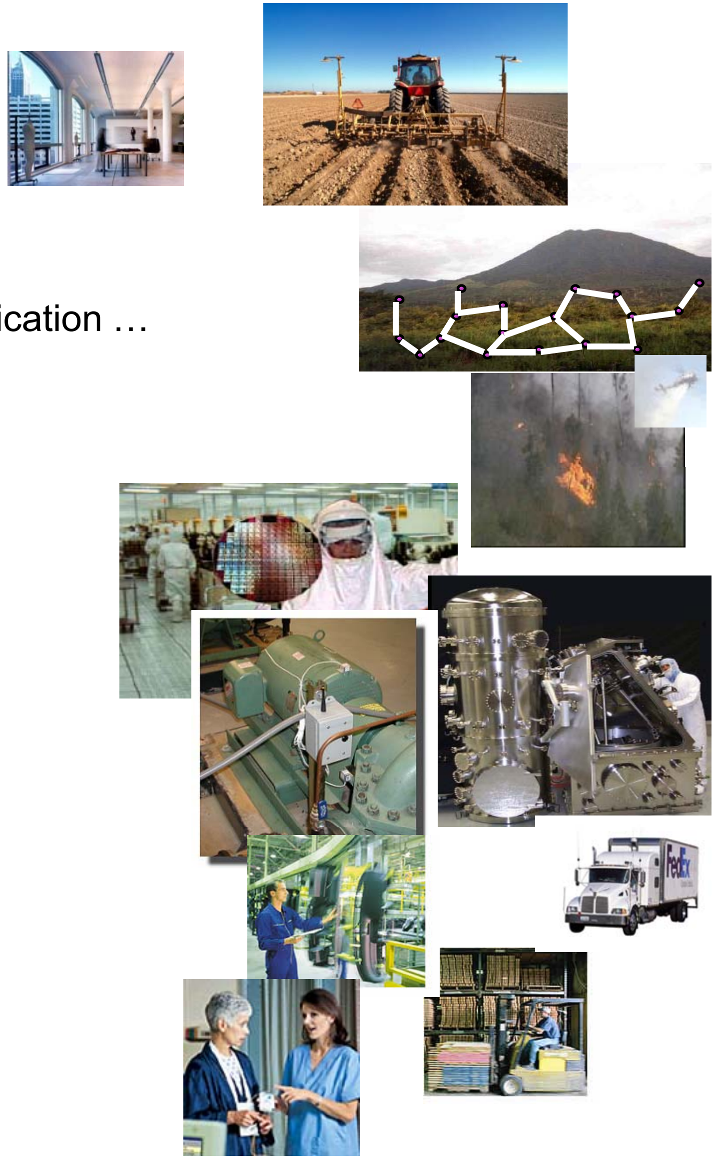
Improve Food & H20

Protect Health

High-Confidence Transport

# 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

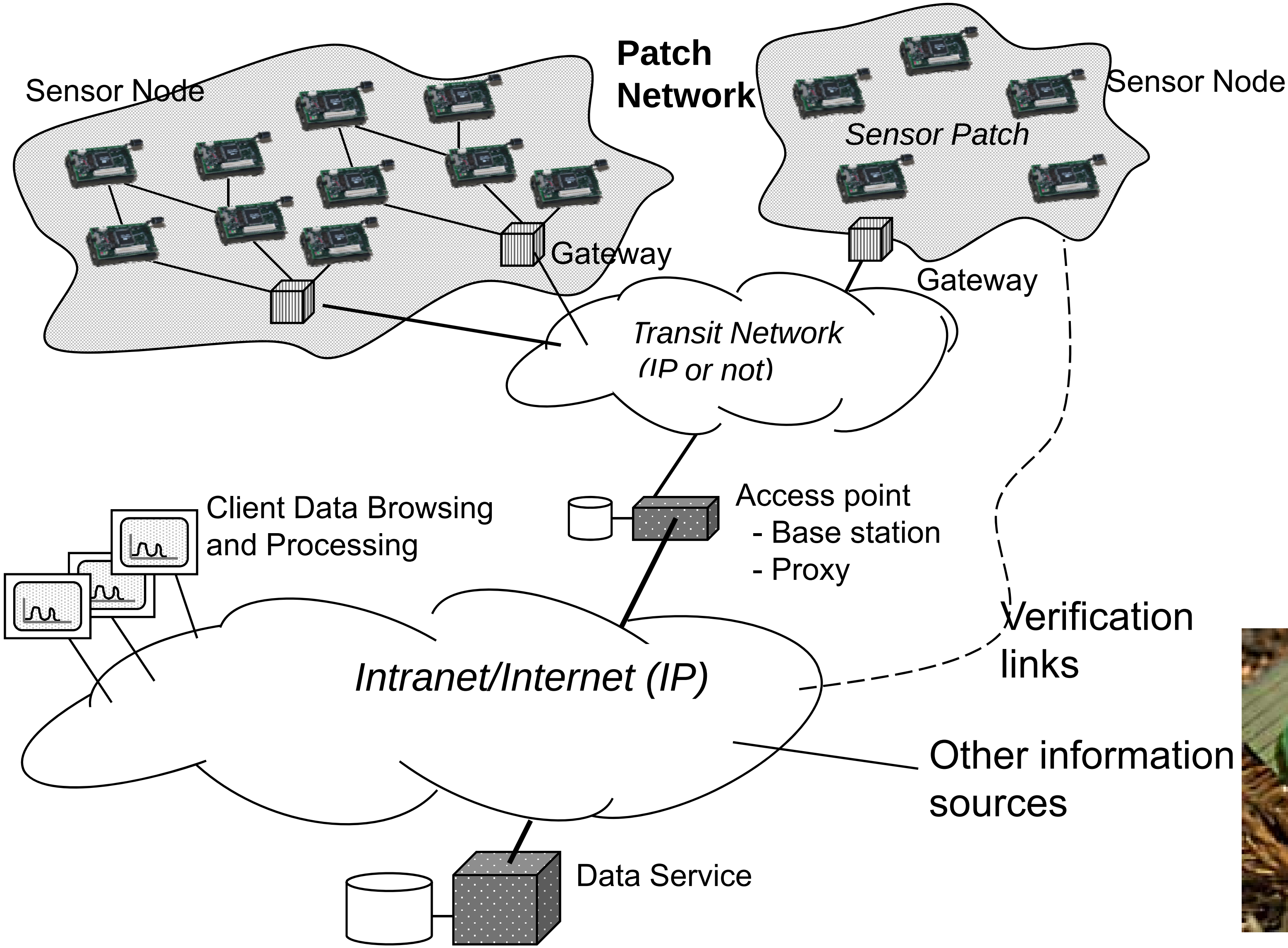


# How to connect sensor networks

- IP/USN
- SpoVNet
- P2P Overlay

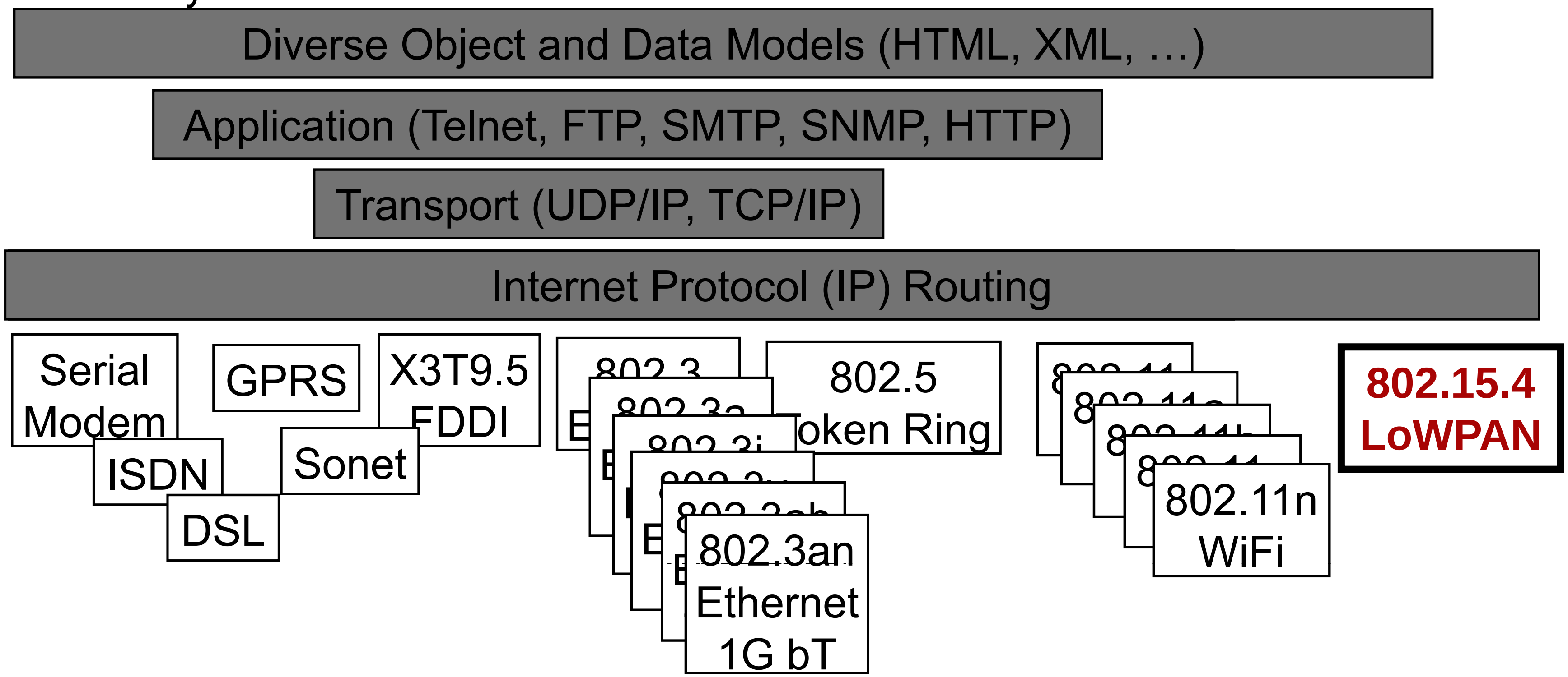
# IP/USN

# 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



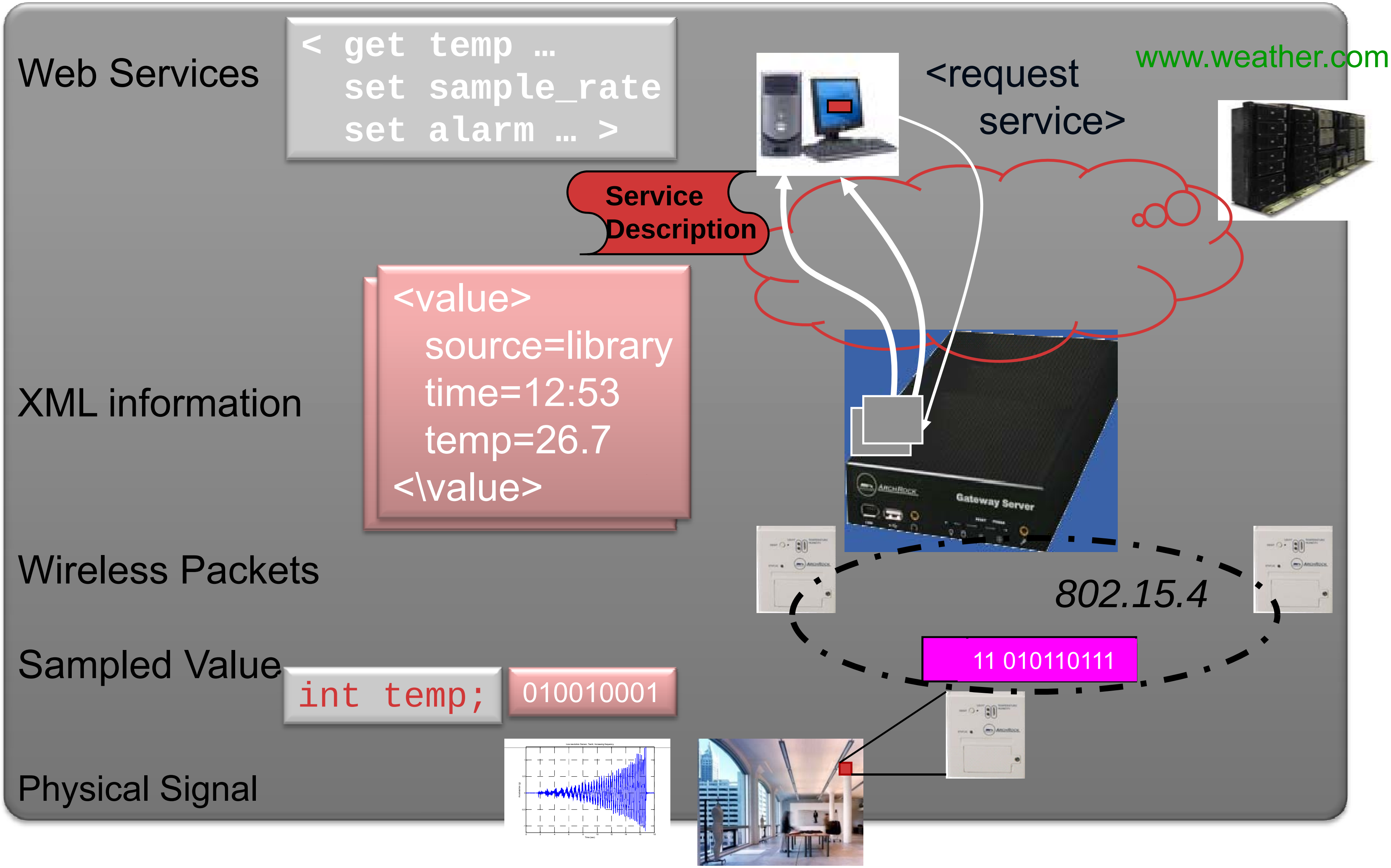
# But, …

- 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.
- 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

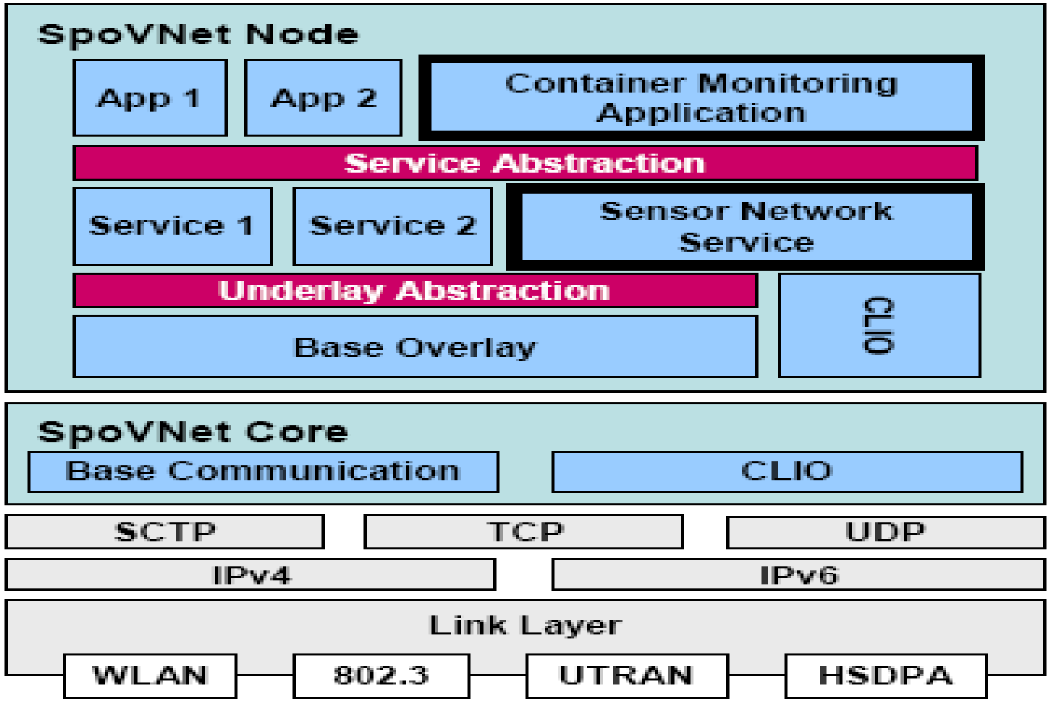
# Cargo Tracking System

- 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

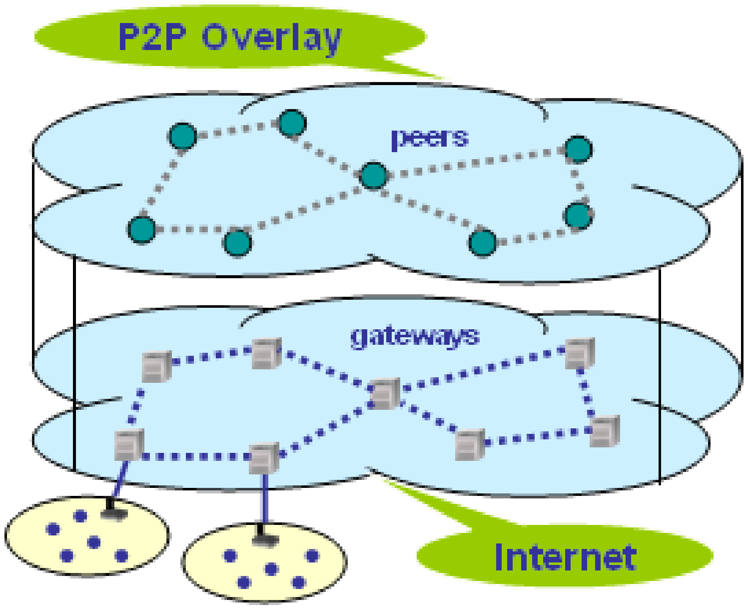
# P2P Overlay Network for Sensor Network

# 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

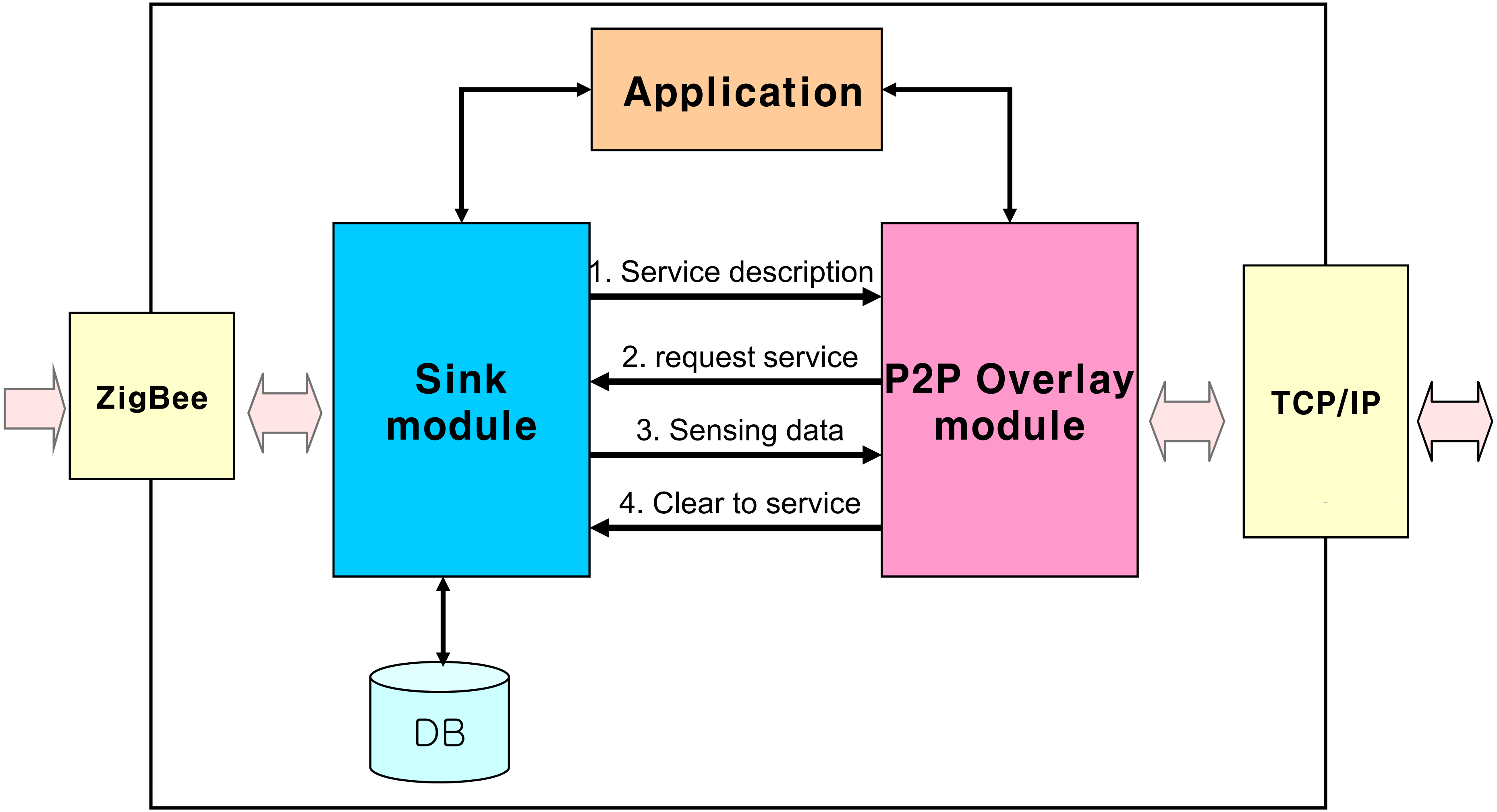



[Lei Shu, SAINT 2008]

# P2P USN Approach

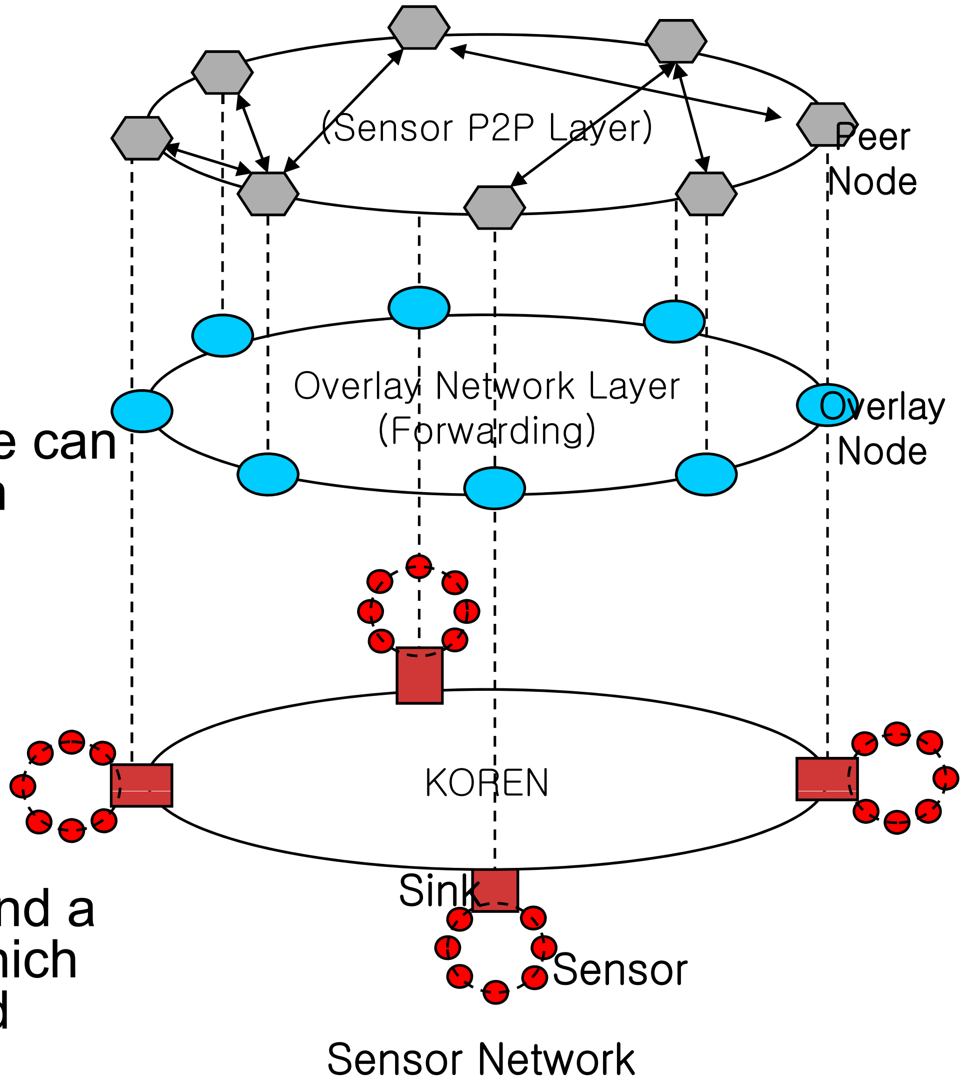
- General P2P overlay network for USN Service
  - If a P2P peer software is installed in sink nodes, sensor nodes, and users, all USNs can be shared by users and other USNs.
  - USN application service is possible without its specific USNs
- Service Scenarios
  - A peer node (user) can find sensor networks 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

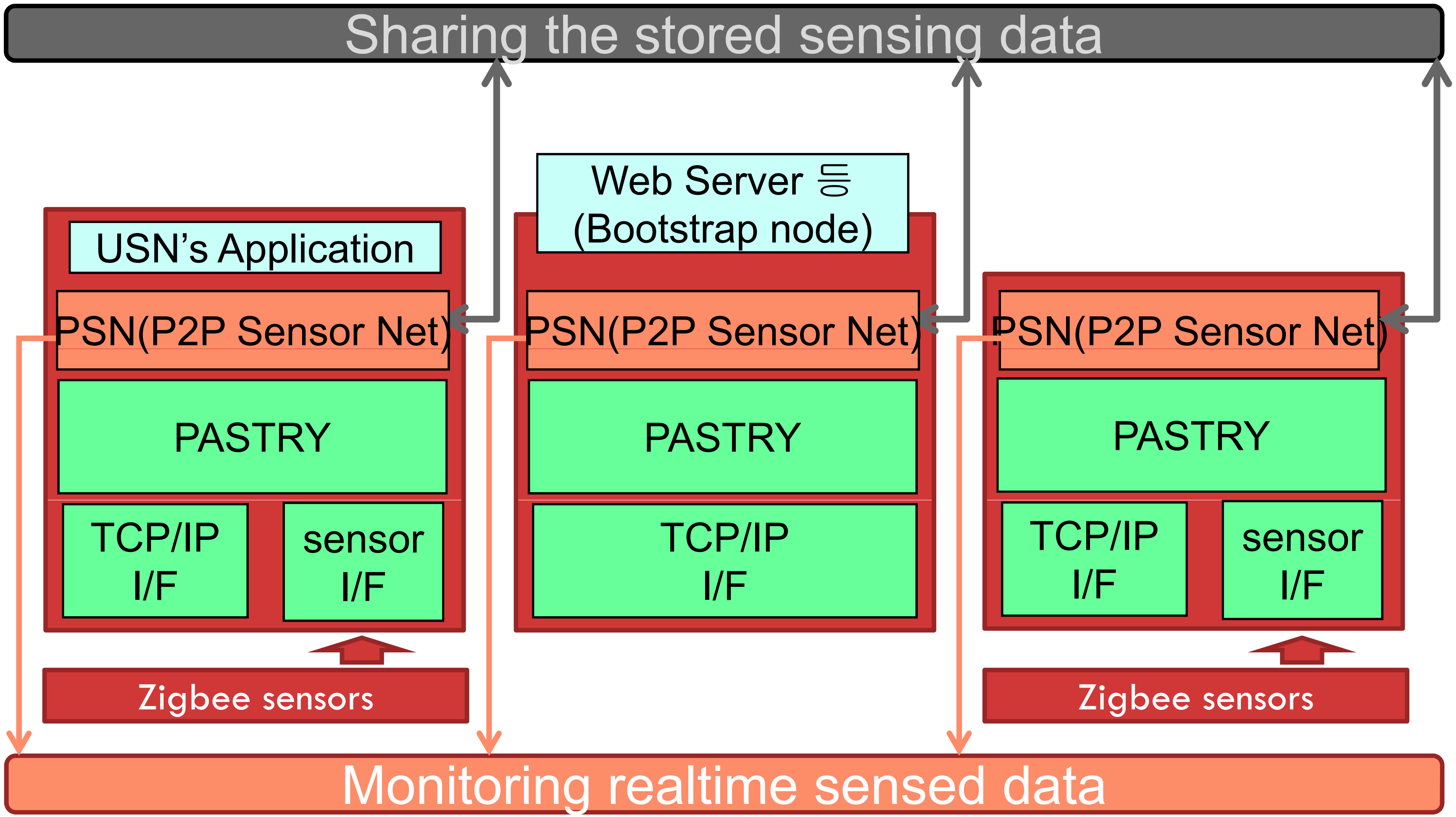


# Sensor P2P Service for Sharing USNs

- 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.

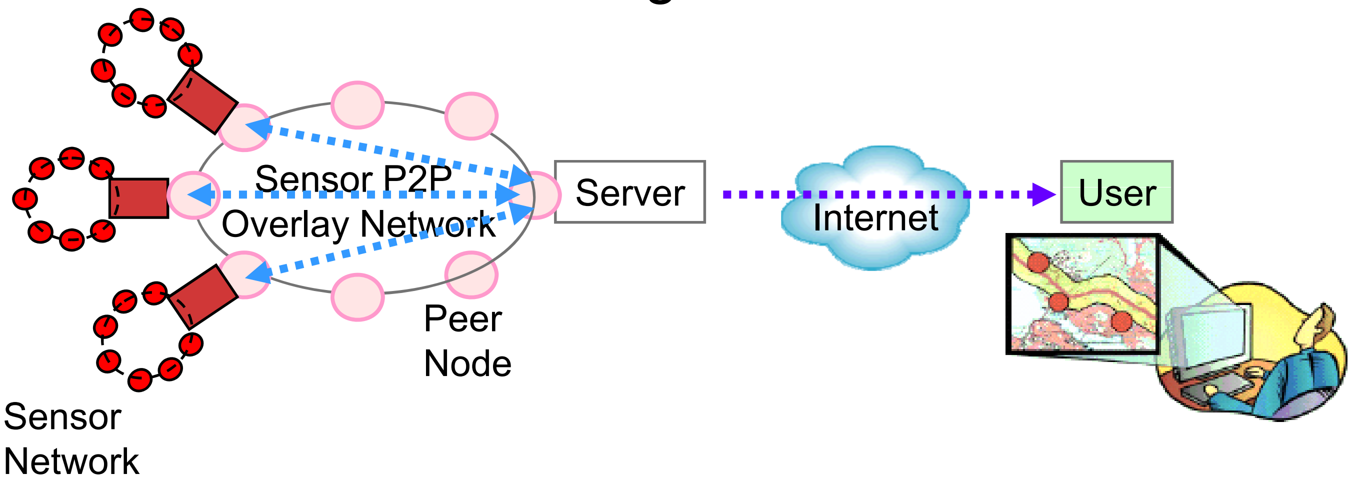


# Peer Node's Architecture

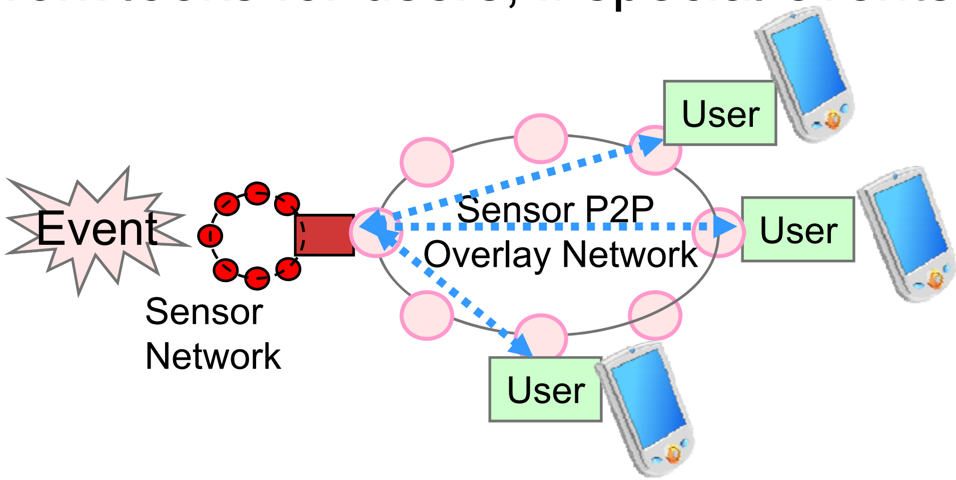


# P2P USN Service Scenarios

- An Application server finds and gathers information.




- Sensor network looks for users, if special events happen



# WMN

# Overview

Node Types

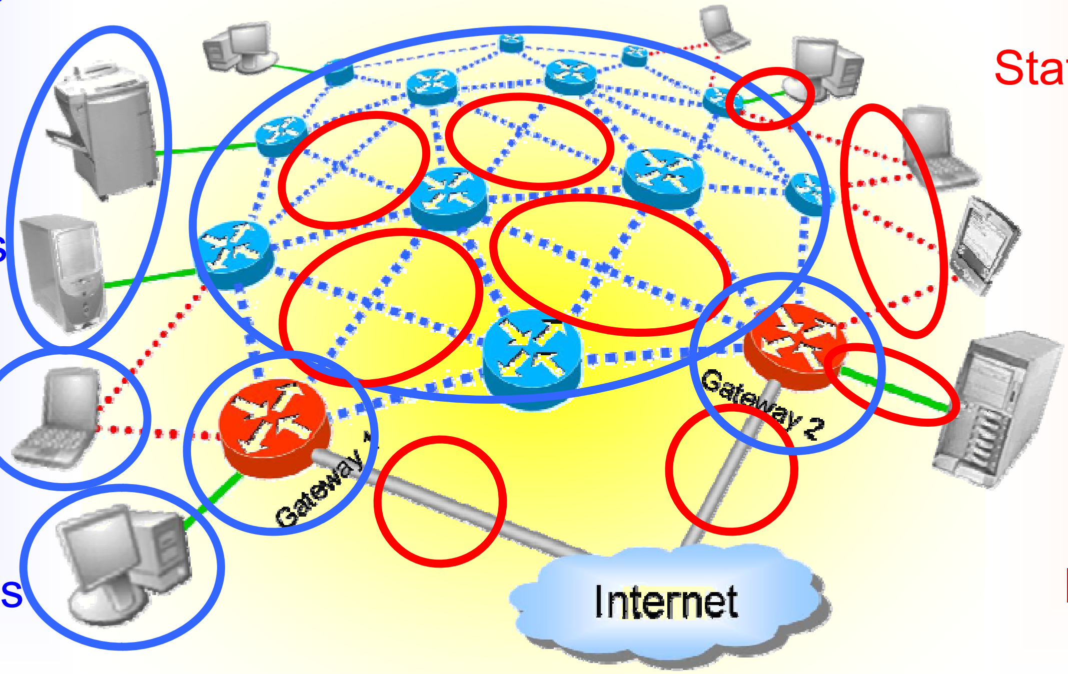
Wireless routers

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

# A NOVEL ARCHITECTURE FOR FUTURE WIRELESS MESH NETWORK

Kejie Lu, Sastri Kota,
Univ of North Texas

# Introduction

- Challenge
  Although Providing Internet access is the main application, WMN will become a service platform for numerous applications in the Pervasive Computing Age.
  - provide sufficient connectivity for a large number of entities in the network
  - support a variety of Quality-of-Service requirements

- Proposal
  Novel framework to design the future wireless mesh network
  - Overlay network architecture that is based on hypernetwork
  - Network Coding

# Background and Related works

- HYPERGRAPH AND HYPERNETWORKS

Hypergraph H = (V,E)
- a set V = *{v1, v2, · · · , vN}* of node
- a set *E =*{*e1, e2, · · · , eM*} of hyper edges

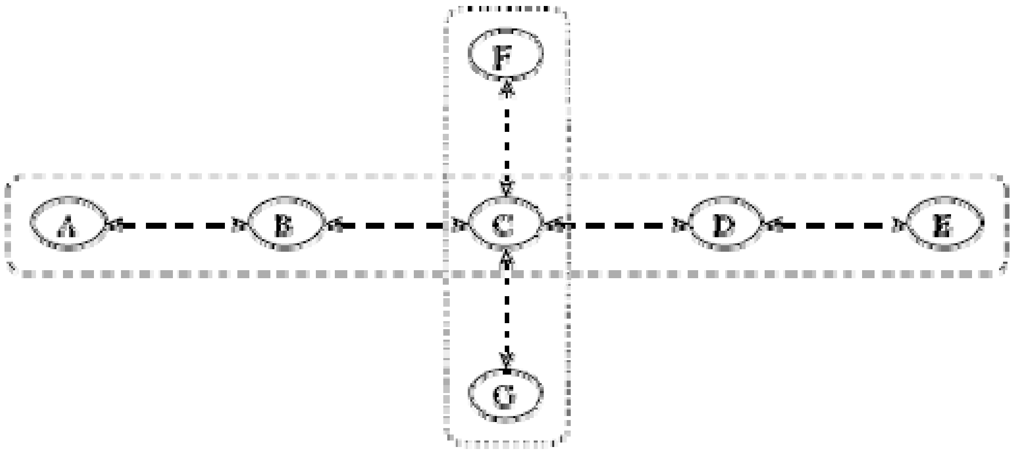



Figure 1. An example of a hypernetwork.

Within a hyper channel, a predefined schedule in the time domain is used to provide connectivity between two nodes or amongst a group of nodes.

# Why Hyperchannel works?

- Compared to regular graph, the key feature of hypergraph is that a hyperchannel can provide connectivity for multiple nodes in the hyperedge.
- multiple hyperedges can be used to establish a hyperpath, which can further improve the connectivity.
- The main distinction is that a hyperchannel can provide connectivity for all participating nodes, while the existing tunnel model can only provide connection for each pair of end nodes.

# Background and Related works

- NETWORK CODING

a) Background of Network Coding

Combines independent information at intermediate node and extract it at receiver or another intermediate node

$$y_k(t) = a_k \times x_k(t - d_k)$$

$x_k(t)$, *where parameter* $k$ *represents* the sequence number and $t$ *denotes the time.*

$d_k$ *is the delay for the k-th packet and* $a_k$ *can be 1* or 0, which means that the packet passed the router, or was dropped, respectively

If network coding is used, then the output of the router can be expressed

$$y_k(t) = f(x_k(t), x_{k-1}(t), \cdots, x_{k-M}(t))$$

the output packet is a function, denoted as $f(\cdot\cdot\cdot)$, *of some packets that have been received previously.*

# Background and Related works

## b) Network Coding for A Single Multicast Connection

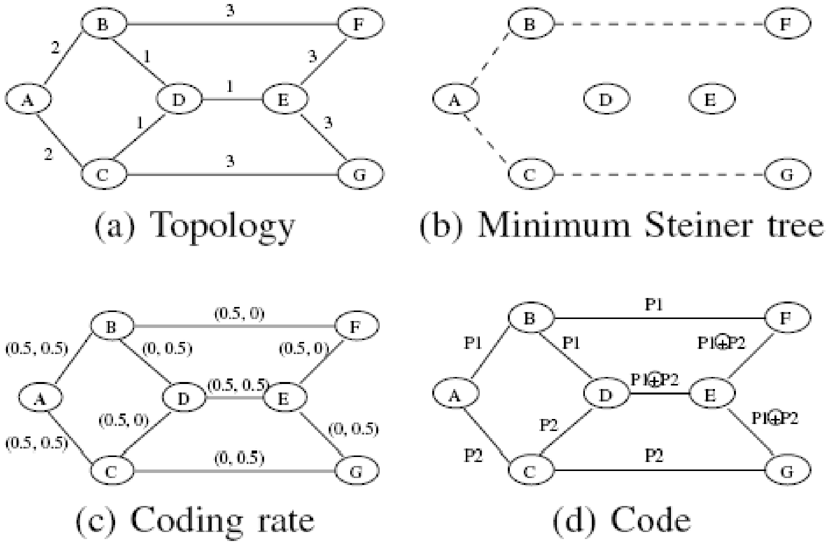



Figure 2. An example of network coding for a multicast connection.

From (b), Calculate that the cost of the tree is 10 (2+3+2+3)

From (d), the cost for the network coding approach is 9.5

(1+1+0.5+0.5+0.5+1.5+1.5+1.5+1.5)

# Background and Related works

## c) Network Coding for Multiple, Simultaneous, Unicast Flows

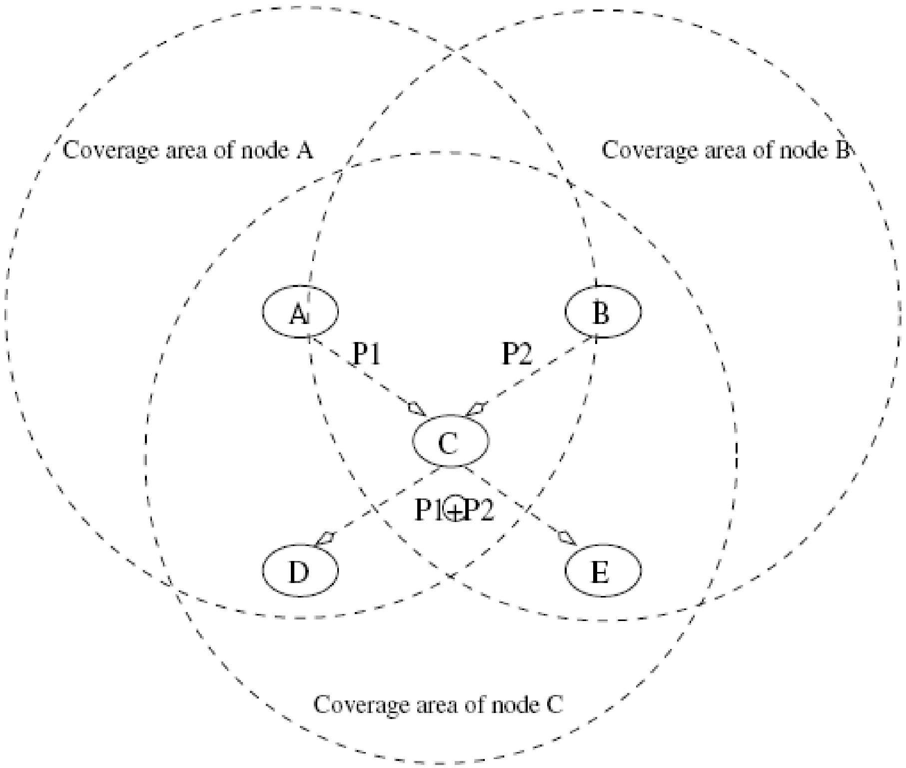



Figure 3. An example of network coding for two unicast flows.

# 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.

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

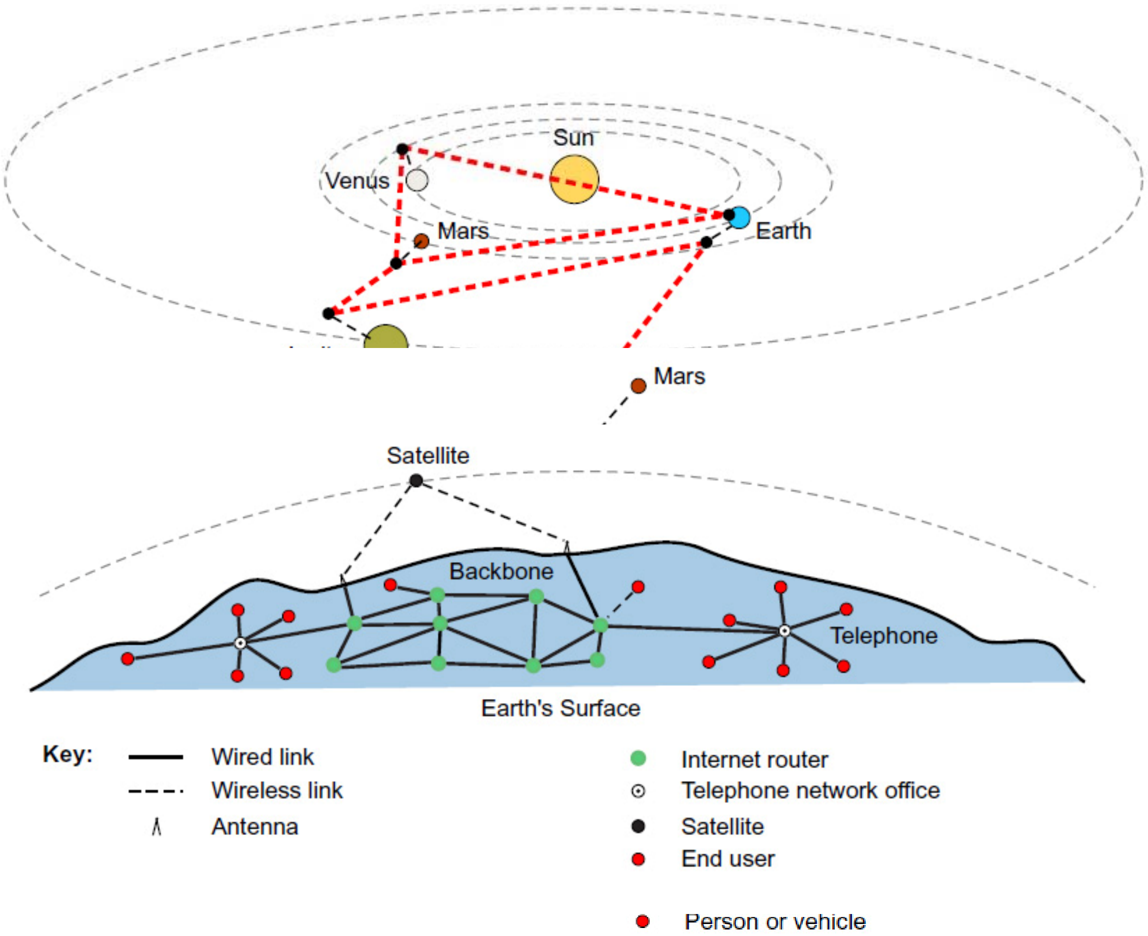
# Future Internet Access Network Technologies: Delay Tolerant Network

# 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



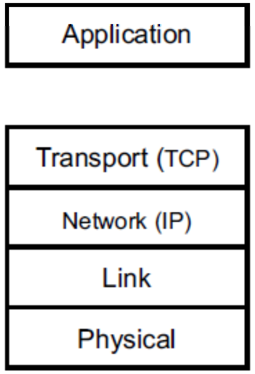
# Why DTNs?

- Current Internet was designed for
  - Continuous, bidirectional end-to-end path
  - Short round-trips
  - Symmetric data rates
  - Low error rates

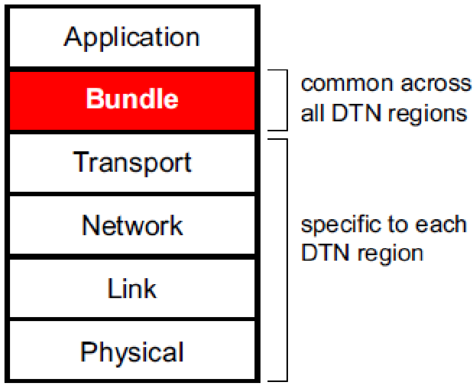
- Many evolving and challenged networks do not confirm to the current Internet's philosophy
  - Intermittent connectivity
  - Long or variable Delay
  - Asymmetric data rates
  - High error rates

# 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 …

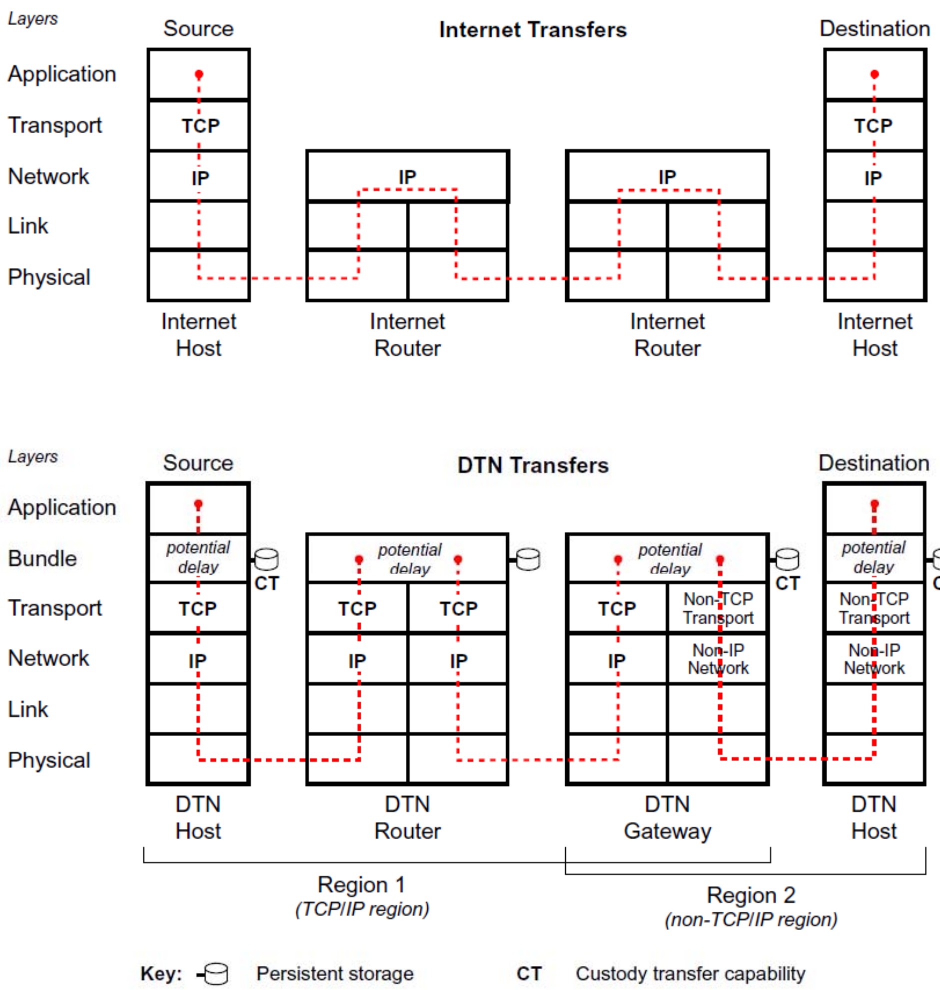



Internet Layers




DTN Layers

# Current Internet vs. DTN Routing



# Types of DTN contacts

- Persistent contacts

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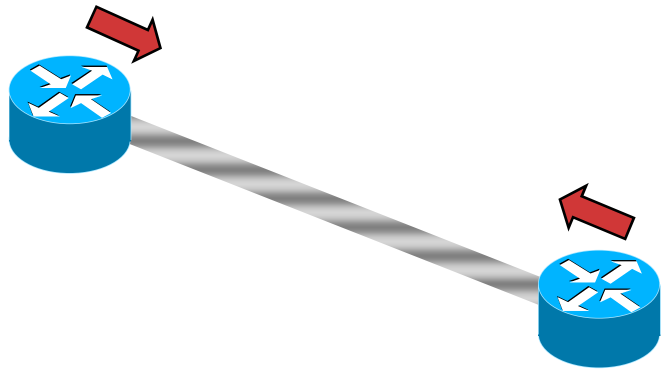
- Persistent contacts
- On-demand contacts

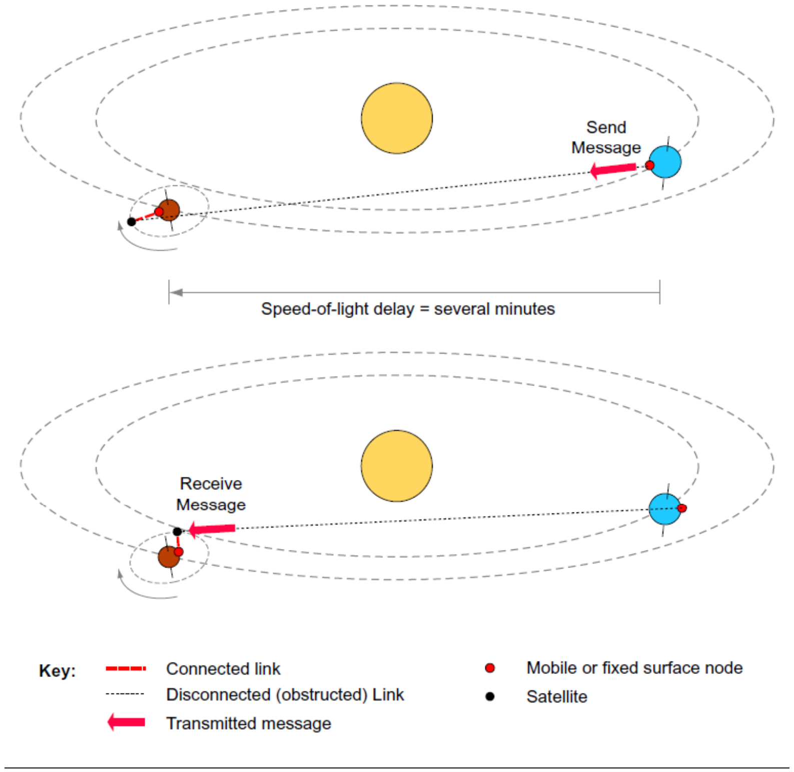


# Types of DTN contacts

- Persistent contacts
- On-demand contacts
- Intermittent –

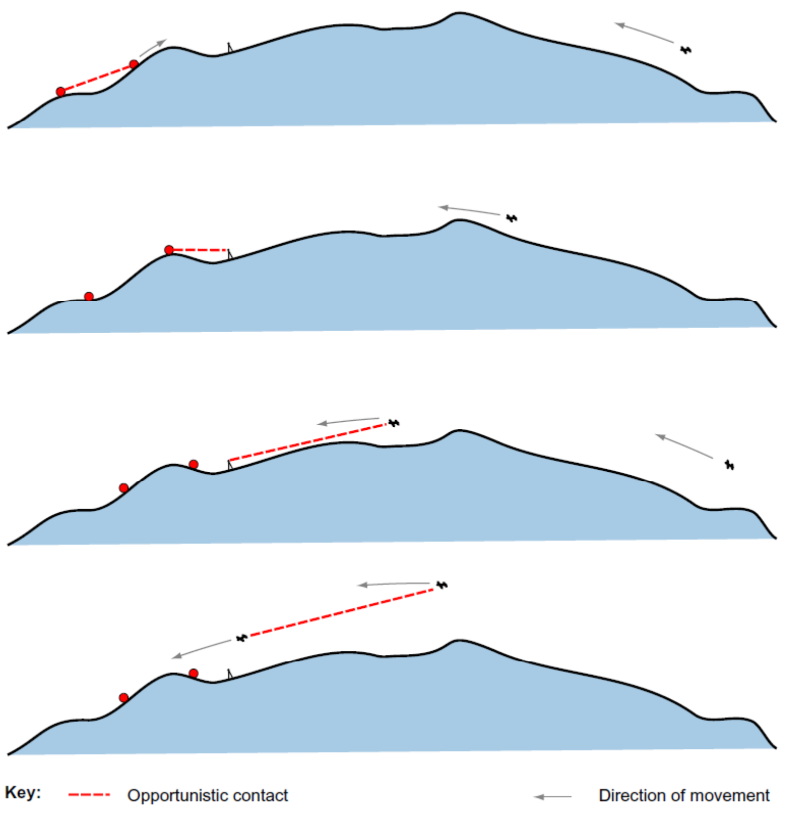
  scheduled contacts

  (predicted contact)



# Types of DTN contacts

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



# Discussions

- Future Internet ?
  - We do not know the picture at this moment.
- Access Network?
  - We can think still there will be need to connect small things (sensors, gadget, or mobile devices) to the NETWORKs.
- Major Candidates
  - Sensor Networks
  - WMN (Wireless Mesh Network)
  - DTN