Wireless Ad hoc Network

A. Prof. Wei Liu (刘威)

Dept. of Electronics and Information Eng.
Huazhong University of Science and Technology

2008.06
Lecture 15

Applications of Ad hoc networks
Outline

- Sensor networks
- Military applications
- Other Applications
Outline

- Sensor networks
  - What is sensor network? Why sensor network?
  - Sensor node platforms
  - Sensor networks: a cooperative approach
  - Communication architecture and protocol stack of sensor network
  - Sensor network: design challenges
  - Several famous sensor network applications
Sensor networks

What is sensor network?

- A sensor network is composed of a large number of sensor nodes, which are densely deployed either inside the phenomenon or very close to it.
- The position of sensor nodes need not be engineered or pre-determined. This allows random deployment in inaccessible terrains or disaster relief operations.
Difference between Sensor Networks and Ad hoc networks

- Network components
  - The number of sensor nodes in a sensor network can be several orders of magnitude higher than the nodes in an ad hoc network.
  - Sensor nodes are densely deployed.
  - Sensor nodes are prone to failures.

- Network topology
  - The topology of a sensor network may not change very frequently.
  - Sensor nodes may not have global identification (ID) because of the large amount of overhead and large number of sensors.

- Communication
  - Sensor nodes mainly use broadcast communication paradigm whereas most ad hoc networks are based on point-to-point communications.

- Energy constraint
  - Sensor nodes are limited in power, computational capacities, and memory.
Why sensor network?

- Intimate connection with its immediate environment.
- No disturbance to environment, animals, plants, etc.
- Avoid unsafe or unwise repeated field studies
- Economical method for long-term data collection. One deployment, multiple utilizations

Some application areas of the sensor network are health, military, and security
Outline

- Sensor networks
  - What is sensor network? Why sensor network?
  - Sensor node platforms
  - Sensor networks: a cooperative approach
  - Communication architecture and protocol stack of sensor network
  - Sensor network: design challenges
  - Several famous sensor network applications
Sensor node platforms

- RSC WINS & Hidra
- Sensoria WINS
- UCLA’s iBadge
- UCLA’s Medusa MK-II
- Berkeley’s Motes
- Berkeley Piconodes
- MIT’s µAMPS
- And many more…

- Different points in (cost, power, functionality, form factor) space
Sensor networks

Rockwell WINS & Hidra Nodes

- Consists of 2”x2” boards in a 3.5”x3.5”x3” enclosure
  - StrongARM 1100 processor @ 133 MHz
  - 4MB Flash, 1MB SRAM
- Various sensors
  - Seismic (geophone)
  - Acoustic
  - Magnetometer,
  - Accelerometer, temperature, pressure
- RF communications
  - Connexant’s RDSSS9M Radio @ 100 kbps, 1-100 mW, 40 channels
- eCos RTOS
- Commercial version: Hidra
  - μC/OS-II
  - TDMA MAC with multihop routing
- http://wins.rsc.rockwell.com/
## Sensor networks

**Berkeley Motes**

- Devices that incorporate communications, processing, sensors, and batteries into a small package
- Atmel microcontroller with sensors and a communication unit
  - RF transceiver, laser module, or a corner cube reflector
  - temperature, light, humidity, pressure, 3 axis magnetometers, 3 axis accelerometers
- TinyOS

### Sensor Node Architecture

<table>
<thead>
<tr>
<th>Component</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFM 90030</td>
<td>916.3 MHz</td>
</tr>
<tr>
<td>ADXL335</td>
<td>Accelerometers 3-axis</td>
</tr>
<tr>
<td>Atmel MCU</td>
<td>4K Flash</td>
</tr>
<tr>
<td>Microchip 256Kbits</td>
<td></td>
</tr>
<tr>
<td>BnB Sensors</td>
<td>AD97841 4-Channel</td>
</tr>
<tr>
<td>Honeywell</td>
<td>Humidity Sensor</td>
</tr>
<tr>
<td>ExerTech</td>
<td>Temperature Sensor</td>
</tr>
</tbody>
</table>

**TinyOS**

- light, temperature, 10 kbps @ 20m
Two processors, Atmel ATMEGA and TI DSP C5416
- Wireless Communication using Bluetooth
- Main Application is Ibadge & Smart Kindergarten
Outline

- Sensor networks
  - What is sensor network? Why sensor network?
  - Sensor node platforms
  - Sensor networks: a cooperative approach
  - Communication architecture and protocol stack of sensor network
  - Sensor network: design challenges
  - Several famous sensor network applications
These sensor nodes have powerless CPU and small RAM so that they are not able to perform complex tasks individually.

Solution: All nodes in the sensor network process tasks cooperatively.
Sensor networks

Single Sensor Approach

- Need sensitive sensors at the sensor node
  - low SNR, no spatial diversity
- Lots of centralized processing

Wireless Ad hoc network – Lecture 15
Communication may be single hop or multiple hop

- Can get way with poorer sensors
  - spatial diversity (beamforming), better SNR
- Central processing means high bandwidth
  - raw data sent back… power used for communication
Sensor networks

Networked Sensors: Distributed Approach

- Sensors coordinate: local processing among neighbors to combine their results
  - lower network traffic, higher-level sensory tasks
- Enable large scale, dynamically changing, robust sensor colonies

*Wireless Ad hoc network – Lecture 15*
Outline

- Sensor networks
  - What is sensor network? Why sensor network?
  - Sensor node platforms
  - Sensor networks: a cooperative approach
  - Communication architecture and protocol stack of sensor network
  - Sensor network: design challenges
  - Several famous sensor network applications
Communication architecture

- Each of these scattered sensor nodes has the capabilities to collect data and route data back to the sink and the end users.

- Data are routed back to the end user by a multihop infrastructureless architecture through the sink as shown in the figure.

- The sink may communicate with the task manager node via Internet or Satellite.
Protocol Stack

The protocol stack consists of:

- application layer,
- transport layer,
- network layer,
- data link layer,
- physical layer,
- power management plane,
- mobility management plane,
- task management plane.
The physical layer

- The physical layer is responsible for frequency selection, carrier frequency generation, signal detection, modulation and data encryption.

- While designing the physical layer for sensor networks, energy minimization assumes significant importance, over and above the decay, scattering, shadowing, reflection, diffraction, multipath and fading effects.
The data link layer

- The data link layer is responsible for the multiplexing of data streams, data frame detection, medium access and error control. It ensures reliable point-to-point and point-to-multipoint connections in a communication network.
- Since the environment is noisy and sensor nodes can be mobile, the MAC protocol must be power aware and able to minimize collision with neighbors’ broadcast.
The network layer

- The network layer takes care of routing the data supplied by the transport layer
  - Power efficiency is always an important consideration.
  - Sensor networks are mostly data centric.
  - An ideal sensor network has attribute-based addressing and location awareness.
The transport layer

- The transport layer helps to maintain the flow of data if the sensor networks application requires it.
- Unlike protocols such as TCP, the end-to-end communication schemes in sensor networks are not based on global addressing. On the other hand, *attribute-based naming* is used to indicate the destinations of the data packets.
The application layer

- Depending on the sensing tasks, different types of application software can be built and used on the application layer.

- Three types of application layer protocols:
  - Sensor management protocol (SMP)
  - Task assignment and data advertisement protocol (TADAP)
  - Sensor query and data dissemination protocol (SQDDP),
Management plane

- The power management plane manages how a sensor node uses its power.
- For example, the sensor node may turn off its receiver after receiving a message from one of its neighbors. This is to avoid getting duplicated messages.
- Also, when the power level of the sensor node is low, the sensor node broadcasts to its neighbors that it is low in power and cannot participate routing messages.
The mobility management plane

- The mobility management plane detects and registers the movement of sensor nodes, so a route back to the user is always maintained, and the sensor nodes can keep track of who are their neighbor sensor nodes.
- By knowing who are the neighbor sensor nodes, the sensor nodes can balance their power and task usage.
The task management plane

- The task management plane balances and schedules the sensing tasks given to a specific region. Not all sensor nodes in that region are required to perform the sensing task at the same time.

- As a result, some sensor nodes perform the task more than the others depending on their power level.
Sensor networks

Architecture Summary

- These management planes are needed, so that sensor nodes can work together in a power efficient way, route data in a mobile sensor network, and share resources between sensor nodes. Without them, each sensor node will just work individually.

- From the whole sensor network standpoint, it is more efficient if sensor nodes can collaborate with each other, so the lifetime of the sensor networks can be prolonged.
## Protocol Samples

<table>
<thead>
<tr>
<th>Layer</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application Layer</td>
<td>Habitat Monitoring, Tracking etc.</td>
</tr>
<tr>
<td>Network Layer</td>
<td></td>
</tr>
<tr>
<td>Topology / Node Coordination</td>
<td>SPAN, GAF</td>
</tr>
<tr>
<td>MAC Layer</td>
<td>802.11, SMAC, MACAW, PAMAS, TDMA, CSMA</td>
</tr>
<tr>
<td>Physical Layer</td>
<td>RF, Infrared, Optical</td>
</tr>
</tbody>
</table>

On the other side: cross-layer design is widely used in sensor network
## MAC Layer Protocols for Ad Hoc Networks

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSMA/CA</td>
<td>Carrier Sense Medium Access with Collision Avoidance</td>
</tr>
<tr>
<td>MACA</td>
<td>Medium Access Collision Avoidance, Uses RTS/CTS to acquire Channel and avoid Hidden Terminal Problem</td>
</tr>
<tr>
<td>MACAW</td>
<td>(Medium Access Control protocol Wireless LANS) Similar to MACA, except has extra control packets, ACKs and backoff mechanism</td>
</tr>
<tr>
<td>PAMAS</td>
<td>Power Aware Multi Access protocol with Signaling for Ad Hoc Networks: uses two separate channels, one for control packets and one for data packets. It puts the nodes to sleep when the neighbor is transmitting.</td>
</tr>
<tr>
<td>IEEE 802.11</td>
<td>Uses RTS/CTS/DATA/ACK sequence, and physical and virtual carrier sense for collision avoidance.</td>
</tr>
</tbody>
</table>
### Mac Layer Protocols for Sensor Network

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Summery</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMACS</td>
<td>Self Organizing Medium Access Control for Sensor Networks, Uses a TDMA like frame combined with FDMA, CDMA to avoid interference among nodes and provide multiple access.</td>
</tr>
<tr>
<td>S-MAC</td>
<td>Periodic Listen and Sleep, Collision and Overhearing Avoidance, Message Passing, Implemented over Berkeley Mote.</td>
</tr>
<tr>
<td>TDMA-based MAC protocol</td>
<td>Assumes a gateway per cluster where the gateway assigns the time slots for each node.</td>
</tr>
<tr>
<td>Adaptive Rate Control</td>
<td>Good for per node fairness. Uses adaptive rate control to adapt the originating data and route-thru traffic. Rate control mechanism uses linear increase and multiplicative decrease where each one. Their CSMA scheme uses sensor sampling phase shift to avoid capturing effect.</td>
</tr>
<tr>
<td>Random Delay</td>
<td></td>
</tr>
</tbody>
</table>

*Wireless Ad hoc network – Lecture 15*
Routing Protocols

• LEACH (MIT)
• SPEED (University of Virginia)
• SPINs (MIT)
• Directed Diffusion (UCLA)
• TTDD (UCLA)
• GEAR (UCLA, ISI)
• GRAdient Broadcast
• ARRIVE (Berkeley)
• Highly-Resilient Energy-Efficient Multipath Routing (UCLA)
• Rumor Routing (UCLA)
• Stream Enabled Routing Protocol (Georgia Tech, in review)
Span: An Energy-Efficient Coordination Algorithm for Topology

- Topology Generation protocol
- Elect / Rotate Coordinators
- Uses an eligibility rule to determine whether to become a coordinator
- Nodes periodically broadcast messages to update any change in topology
- Capacity Preservation vs. network lifetime

Disadvantages:
- Urgent delivery service not possible
- Should be able to control MAC layer WakeUp
- Simulation experiments based on 802.11 & Geographic Forwarding Routing.

Wireless Ad hoc network – Lecture 15
**GAF: Geographical Adaptive Fidelity**

- Location aware nodes build a virtual Grid
- Nodes inside a square equal in routing
- Nodes in same grid coordinate sleep/wakeup

- Load Balancing through alternative wakeup / sleep

**GAF State Transitions:**

- Node Broadcast discovery message and enters active state
- After some time Node returns to discovery and release active state for other nodes
- Node in sleep state moves to discovery after an application-dependent time
- Application dependent ranking decides coordinator among nodes.
ASCENT: Adaptive Self-Configuring Sensor Network Topology

• Neighbor discovery phase to find the number of actively transmitting neighbors

• Join decision phase

• May join temporarily to test if it contributes to connectivity improvement

• If a node decides to join for a longer time, it enters the active phase

• The join decision is based on the number of neighbors and the rate of message loss

• If the node decides not to join, it enters the adaptive phase where it turns itself off or reduces the transmission range and increase the sensing coverage

• Active nodes can send help messages to recruit more active nodes
LEACH : Low-Energy Adaptive Clustering Hierarchy

Algorithm Overview:
- Advertisement
- Cluster Set-Up (based on the signal strength)
- Schedule Creation
- Data Transmission
- Multiple Clusters (CDMA, avoid degradation in one cluster from transmission in another cluster)
- Hierarchical Clustering.

Disadvantages:
- Incomplete Comparison with any other protocol except direct min energy communication.
- Suggest using the same hierarchy structure for cluster-heads up to base station for routing. Unclear if that is optimal for routing from the cluster-heads.
SPEED: A Real Time Routing Protocol for Sensor Networks

3 Mechanisms:
• Regular Unicast
• Area Multicast
• Area AnyCast

Algorithm Overview:
• Neighbor Beacon Exchange
• Receive Delay Estimation
• Stateless non-Deterministic Geographic Forwarding
• BackPressure Rerouting to avoid packet drop
• Neighbor set and forwarding set

• the forwarding set is divided into two based on the hop delay

• if no neighbor qualifies, calculate relay ration and based on that forward or drop the packet
Disadvantages:

- No an optimal Congestion Recovery Mechanism (the protocol drops packets when congestion occurs)
- Simulation results do not compare to Sensor protocols. Available only for DSR, AODV, GF.
**SPINs**: Sensor Protocols for Information via Negotiation

Message Types: ADV, REQ & DATA

- Efficient use of Meta Data
- Algorithm: Advertisement of new data, Request for new data, Data transfer. If data compares with previous data no REQ
- No topology information required
- Extremely less computation
- Energy level Threshold in SPIN2

Disadvantages:
- Compared only to Flooding & Gossiping
- Assumes all nodes are interested in Data
- Enhancements could be to partition the network
- Could send the data only to the subset of nodes in routing or interested in data.
Directed Diffusion

- Data Centric, Attribute-Value pairs
- Events Flow towards the originator across multiple paths
- Interest and task Propagation initiated at the sink and propagated through flooding
- Initial gradient setup by node, where gradient consists of data rate value and direction
- Data delivery along reinforced path, selected as an empirically low delay path
- Experimentation required for choosing local rule to use for negative reinforcement

Disadvantages:
- Congestion recovery mechanism Unavailable
- Congestion performance of protocol not verified
- Power efficiency of MAC Layer undefined
- Experiments needed to find the best negative-reinforcement rule (power efficient)
**GEAR: Geographical and Energy-Aware Routing**

**Assumptions:**
- Location, Energy, Neighbor aware Nodes
- Target Region Specific Queries
- Bi-Directional Links
- Static sensors

**Algorithm Overview:**
- Next hop node for packet forwarding chosen on geographical closeness/ or cost basis
- Once packet reaches a target region, recursive geographic Forwarding sends it to destination, or if the density is low, a restricted flooding is used
- Forwarding to Sub Region continues until stop condition: Node is the only one in Sub Region.
- Pure geographical forwarding is used if: 1) number of hops threshold is passed 2) packet reaches nodes with energy depleted 3) Node is near a target region
- Gear is not sensitive to Location Error
- Gear increases the average path length for a packet
Metrics for Comparison of Routing Protocols

- Minimizing energy consumed per packet
- Maximize time to network partition (load balancing)
- Maximize variance in node power levels (load sharing)
- Minimize cost per packet
- Minimize maximum node cost (after some time)

Other factors to consider in addition to power-aware metrics when comparing routing protocols:

- Scalability
- Resilience to node failures
- Amount of overhead messages (such as updates)
- Sensitivity to error (such as error in location)
Outline

- Sensor networks
  - What is sensor network? Why sensor network?
  - Sensor node platforms
  - Sensor networks: a cooperative approach
  - Communication architecture and protocol stack of sensor network
  - Sensor network: design challenges
  - Several famous sensor network applications
Enabling Technologies for applications

- **Embedded**: Control system w/ Small form factor Untethered nodes
  - Embed numerous distributed devices to monitor and interact with physical world

- **Networked**: Exploit collaborative Sensing, action
  - Network devices to coordinate and perform higher-level tasks

- **Sensing**: Tightly coupled to physical world
  - Exploit spatially and temporally dense, in situ, sensing and actuation

*Wireless Ad hoc network – Lecture 15*
Sensor Network: Design Challenges

- Fault Tolerance
- Scalability
- Production costs
- Operating environment
- Sensor network topology
- Hardware constraints
- Transmission media
- Power consumption
Research challenges

- Real-time analysis for rapid response.
- Massive amount of data → Smart, efficient, innovative data management and analysis tools.
- Poor signal-to-noise ratio due to traffic, construction, explosions, ....
- Insufficient data for large earthquakes → Structure response must be extrapolated from small and moderate-size earthquakes, and force-vibration testing.
Outline

Sensor networks
- What is sensor network? Why sensor network?
- Sensor node platforms
- Sensor networks: a cooperative approach
- Communication architecture and protocol stack of sensor network
- Sensor network: design challenges
- Several famous sensor network applications
  - Habitat/ Ecophysiology Monitoring
  - Community/Building Monitoring
  - Military Monitoring
Sensor networks application

Habitat Monitoring
- Petrel habitat on Great Duck Island in Maine.
- Questions to answer:
  - Usage pattern of nesting burrows over the 24-72 hour cycle
  - Changes in the burrow and surface environmental parameters
  - Differences in the micro-environments with and without large numbers of nesting petrels
- Primitive requirement: no human disturbance
Sensor networks application

Approach to habitat monitoring

Wireless Ad hoc network – Lecture 15
Sensor networks application

- The Thermopile data of Great Duck Island Burrow 95

![Graph showing Thermopile Data of Great Duck Island Burrow 95](image)
Sensor networks application

Estuarine Environmental Observation and Forecasting System

- Observation and forecasting system for the Columbia River Estuary
Sensor networks application

Estuarine Environmental Observation and Forecasting System

- Real-time observations
  - Estuarine and offshore stations
- Numerical modeling
  - Produce forecast, hindcast of circulation
- Virtualization & application
  - Vessel survey, navigation fishing, etc…
Sensor networks application

Ecosystem Monitoring

- Understand response of wild populations (plants and animals) to habitats over time.
- Data acquisition of physical and chemical properties, at various spatial and temporal scales, appropriate to the ecosystem, species and habitat.
Sensor networks application

Requirements for Habitat/Ecophysiology Applications

- Diverse sensor sizes (1-10 cm), spatial sampling intervals (1 cm - 100 m), and temporal sampling intervals (1 ms - days), depending on habitats and organisms.
- Naive approach → Too many sensors → Too many data.
  - In-network, distributed signal processing.
- Wireless communication due to climate, terrain, thick vegetation.
- Adaptive Self-Organization to achieve reliable, long-lived, operation in dynamic, resource-limited, harsh environment.
- Mobility for deploying scarce resources (e.g., high resolution sensors).
**Sensor networks application**

- Other application examples:
  - detection on the seabed outside the port
Outline

- Sensor networks
  - What is sensor network? Why sensor network?
  - Sensor node platforms
  - Sensor networks: a cooperative approach
  - Communication architecture and protocol stack of sensor network
  - Sensor network: design challenges
  - Several famous sensor network applications
    - Habitat/ Ecophysiology Monitoring
    - Community/Building Monitoring
    - Military Monitoring
Seismic structure response

- Interaction between ground motions and structure/foundation response not well understood.
  - Current seismic networks not spatially dense enough to monitor structure deformation in response to ground motion, to sample wavefield without spatial aliasing.
- Technology/Applications
  - Identification of seismic events that cause significant structure shaking.
  - Local, at-node processing of waveforms.
  - Dense structure monitoring systems.
Sensor networks application

Field Experiment

• 38 strong-motion seismometers in 17-story steel-frame Factor Building.
• 100 free-field seismometers in UCLA campus ground at 100-m spacing
Contaminant Transport

- Multiple modalities (e.g., pH, redox conditions, etc.)
- Micro sizes for some applications (e.g., pesticide transport in plant roots).
- Tracking contaminant “fronts”.
- At-node interpretation of potential for risk (in field deployment).
Sensor networks application

Research Implications

- Environmental Micro-Sensors
  - Sensors capable of recognizing phases in air/water/soil mixtures.
  - Sensors that withstand physically and chemically harsh conditions.
  - Microsensors.
- Signal Processing
  - Nodes capable of real-time analysis of signals.
  - Collaborative signal processing to expend energy only where there is risk.
Sensor networks application

Transportation and Urban Monitoring

Disaster Response

Inner wall of storm drain

Wireless Ad hoc network – Lecture 15
Sensor networks application

Other application examples:

- Detection of water saturation in the mine
Outline

Sensor networks
  What is sensor network? Why sensor network?
  Sensor node platforms
  Sensor networks: a cooperative approach
  Communication architecture and protocol stack of sensor network
  Sensor network: design challenges
  Several famous sensor network applications
    Habitat/ Ecophysiology Monitoring
    Community/Building Monitoring
    Military Monitoring
Military applications of Ad hoc networks
Military applications of Ad hoc networks

The Art of War

- Military action is important to the nation - it is the ground of death and life, the path of survival and destruction.

- Five things are
  - Way
  - Weather
  - Terrain
  - Leadership
  - Discipline

Sun Tzu: “The Art of War”, 6th century BC
Military applications of Ad hoc networks

Military network requirements

- Military environment is the most difficult for the mobile communication and mobility management
  - Hostile enemy
  - Radio power usage restrictions
    - battery, reveal location, time, and importance of the node
  - Trust models
    - Handling of compromised nodes
  - Quality of service control
    - Not all nodes or packets are equal
  - Need for robustness
    - Fault resilience, automatic repair after failure, redundant routes
  - Need for performance
Military applications of Ad hoc networks

Military network requirements

- In governmental and civilian networks we have
  - Cost issue
    - Protocols and equipment may not be too expensive
- No black/white relation between nodes
  - Not just friend/foe separation
  - Own/allies/neutral/enemy
- Limited radio spectrum
  - Commercial radio licenses
- No predefined trust between nodes
  - In military trust is easy to establish but difficult to keep
  - In commercial networks trust is difficult to establish but easy to keep
Military applications of Ad hoc networks

Typical Military application
Sensor networks application

Military Applications of Smart Dust
Sensor networks application

Smart Dust: Mote

- Passive Transmitter with Corner-Cube Retroreflector
- Active Transmitter with Laser Diode and Beam Steering
- Receiver with Photodetector
- Sensors
- Solar Cell
- Thick-Film Battery
- Power Capacitor
- Analog I/O, DSP, Control

Wireless Ad hoc network – Lecture 15
**Sensor networks application**

**Wolf Pack**

**Introduction**
- DARPA/ATO: $40,000,000$ dollars
- Started from 2001,
- Distributed networking
- Detecting $30MHz - 20GHz$
- Radio communication
- $10.2cm^2 * 25.4cm$ column
- Expected cost with $1000/km^2
Outline

- Sensor networks
- Other Applications of Ad hoc networks
Other Applications of Ad hoc networks

Features:

- Mobility: in order to be able to use the application everywhere, the user should not be limited by range. The range limit is set by the business logic of the application.

- Peer-to-Peer: direct communication between peers is mandatory. This means that the client/server relationship is defined in an ad hoc manner by the application logic (direct interaction between the pieces of software).

- Collocation: all logical interactions between applications must result in a physical interaction between users. This means that in order to be called an ad hoc application, the service has to be location-based.
Other Applications of Ad hoc networks

The different layers of an ad hoc application

<table>
<thead>
<tr>
<th>Ad hoc Application</th>
<th>Ad hoc Application Framework</th>
<th>Location Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>P2P</td>
<td>HTTP</td>
<td></td>
</tr>
<tr>
<td>P2P Low Level</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Other Applications of Ad hoc networks

App#1: The Ubiquitous Flea Market

- The Ubiquitous Flea Market is available wherever you are and at all times.
- It is available on many mobile devices and matches buyers and sellers present within a certain range, the latter being previously defined by the user.
Other Applications of Ad hoc networks

The traditional flea market vs. The ubiquitous flea market

- Available at a certain day and time vs. available at any time
- Walking around takes time and energy vs. whenever mobile device is on(line)
- Different roles clearly separated vs. being able to be buyer and seller
Other Applications of Ad hoc networks

The User Interfaces of Ubiquitous Flea Market

Wireless Ad hoc network – Lecture 15
Other Applications of Ad hoc networks

App #2: Nokia RoofTop Wireless Routing*

- A wireless broadband solution for residential markets, based on a multihop Ad-Hoc (mesh) networking.

- Why Ad-Hoc for © Nokia RoofTop? 
  - Broad coverage by simplifying line-of-sight problems;
  - Does not require large investments in infrastructure and engineering; and
  - Simple and inexpensive to operate and grow the network
Other Applications of Ad hoc networks

© Nokia RoofTop Wireless Routing*
Other Applications of Ad hoc networks

App#3: FriendZone: a suite of mobile Location-based Community Services

- Instant Messenger & Locator (IM&L)
  - locate its network subscribers, whenever their handset is turned on
- Mobile Chat
  - It allows users to exchange textual messages in virtual chat rooms, Nevertheless, the relative distance of chat roommates is available.
- Anonymous Instant Messenger (AIM)
  - The AIM service enables an automatic match of two anonymous users, based on their interests or relative distances
- Privacy Management
Other Applications of Ad hoc networks

FriendZone: user interfaces

1(a) Buddy list
1(b) Locator
2(a) User Profile
2(b) User Profile cont.
2(c) Personal (virtual) picture
2(d) AIM query results
Other Applications of Ad hoc networks

Future commercial applications
Summary

- Wireless Sensor network is a special type of ad hoc networks.
- Research Challenges of wireless Sensor networks
  - Real-time analysis for rapid response.
  - Massive amount of data → Smart, energy efficient, innovative data management and analysis tools.
  - Poor signal-to-noise ratio due to traffic, construction, explosions, ....
- The Wireless sensor network and ad hoc network applications will be seen everywhere in the next few years.
References

References


Thank you!