Introduction: Wireless Ad Hoc Networks

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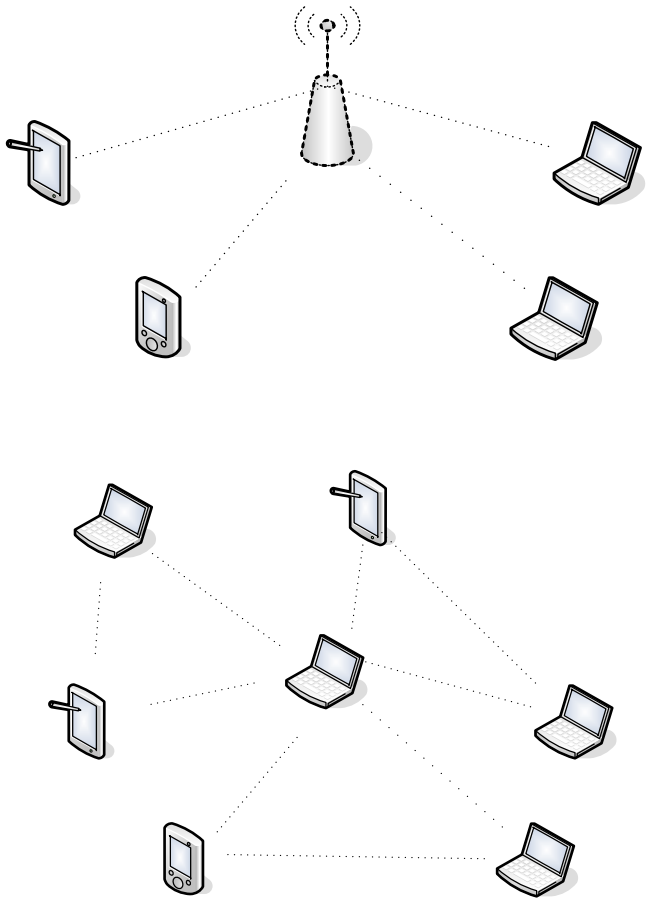
Wireless Networks

- Two types:
  - Infrastructure-based
    - Relies on fixed infrastructure
    - Base stations or access points are fixed and centralized
    - E.g., WLANs, cellular networks
  - Infrastructure-less
    - No centralized access points
    - Ad Hoc networks



Wireless Ad-Hoc Networks

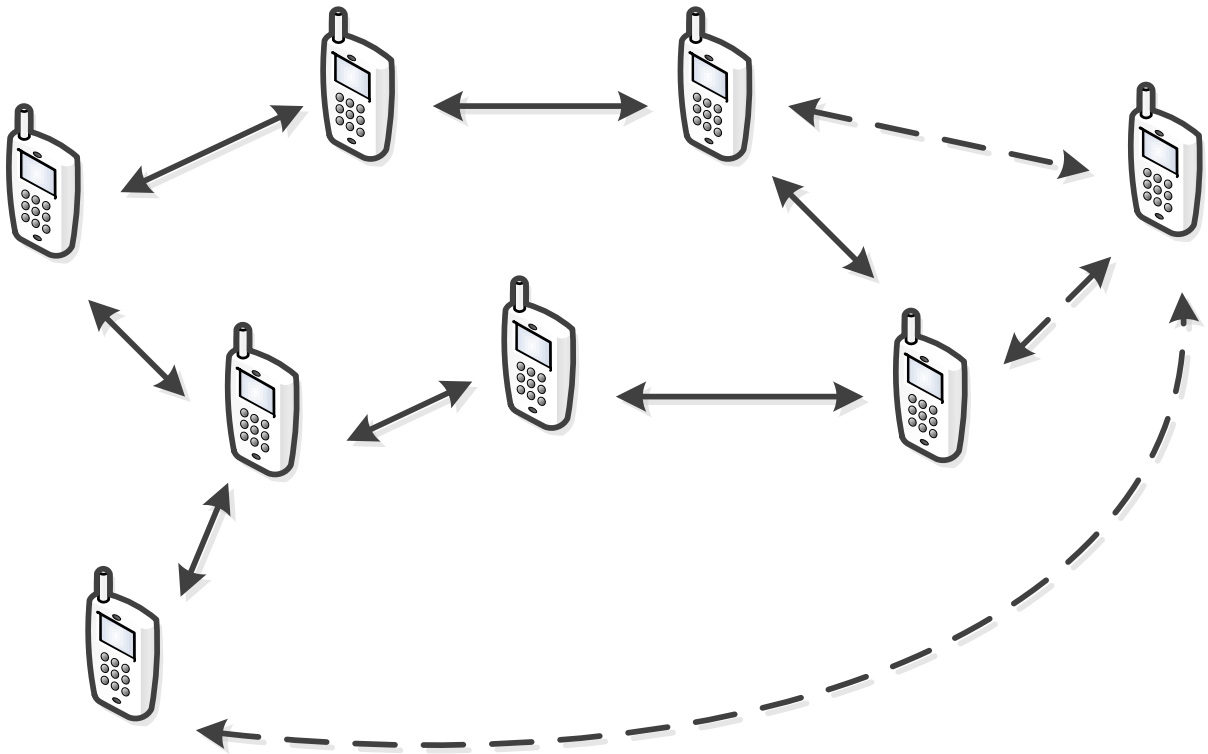


Fig: Dynamic Topology Change in Ad-Hoc Networks

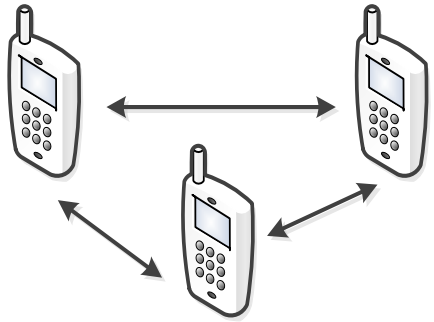
Wireless Ad-Hoc Networks

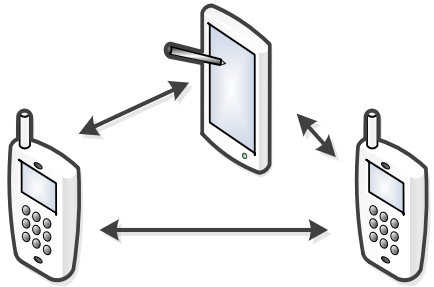
- Multi-hop network that does not require any fixed infrastructure
- Peer nodes take part in relaying information
- Self-organizing and self-configuring
- Situations in which useful:
  - Need to setup a network fast, e.g., times of emergency, relief operations.
  - No access to network infrastructure
  - Not much planning can be afforded to setup the network

Wireless Ad Hoc Networks

Depending on topology and deployment Ad-Hoc Networks may be classified as:

- Homogeneous
  - Consists of nodes having similar characteristic
  - (E.g. Network formed of only smartphones)
- Heterogeneous
  - Consists of nodes with different capabilities
    (E.g. Network formed of PCs, Smartphones and Tablets)





History

- DARPA packet radio network project (1972)
  - Communication in the battlefield by different wireless devices.
  - Several terminals could communicate with one another.
- ALOHA project at University of Hawaii
  - Led to the development of the multi-hop packet radio network (PRNET)
  - Sponsored by ARPA
- PRNET
  - Consists of several mobile radio repeaters, wireless terminals and dedicated mobile stations.
  - Repeaters relay packets from one repeater to another until the packets reach the destination host.
  - Advantages: rapidly deployable, self-initializing, self-organizing, no network management and administration problems.
  - Disadvantages: Problems with media access, error and flow control, routing, etc.

General Concepts

- Ad-Hoc networks are a type of Distributed Wireless Networks
- Ad-Hoc networks operate in Time Division Duplex (TDD) mode – it is not possible to receive and transmit at the same time instant
- Neighbor nodes communicate with each other using single hop wireless technology like Bluetooth, ZigBee and IEEE 802.11 (Ad-hoc mode)
- Nodes which are distant from each other (outside direct transmission range of each other) communicate using a sequence of intermediate nodes which co-operate to forward the traffic to the destination.

Enabling Technologies

- Basic building blocks of MANET communications that enable single hop communications between devices in direct communication range of each other
- Wireless Ad-Hoc Communication Technologies
  - ZigBee (IEEE 802.15.4) – Short Range (~100m) Low Data Rate (<250 kb/s)
  - Bluetooth (IEEE 802.15.1) – for Personal Area Networks (PAN)
  - IEEE 802.11 (in Ad-Hoc Mode) - High Speed Medium range MANETs
  - IEEE 802.16 – High Speed Wide Range
- Wide availability of 802.11 NICs have made this the most widely used technology
- 802.11 not being originally designed for Ad-Hoc networks suffers from various performance issues. However, technologies such as directional antennae, MIMO technologies, OFDM etc. somewhat ameliorate these problems

Comparison of Enabling Technologies

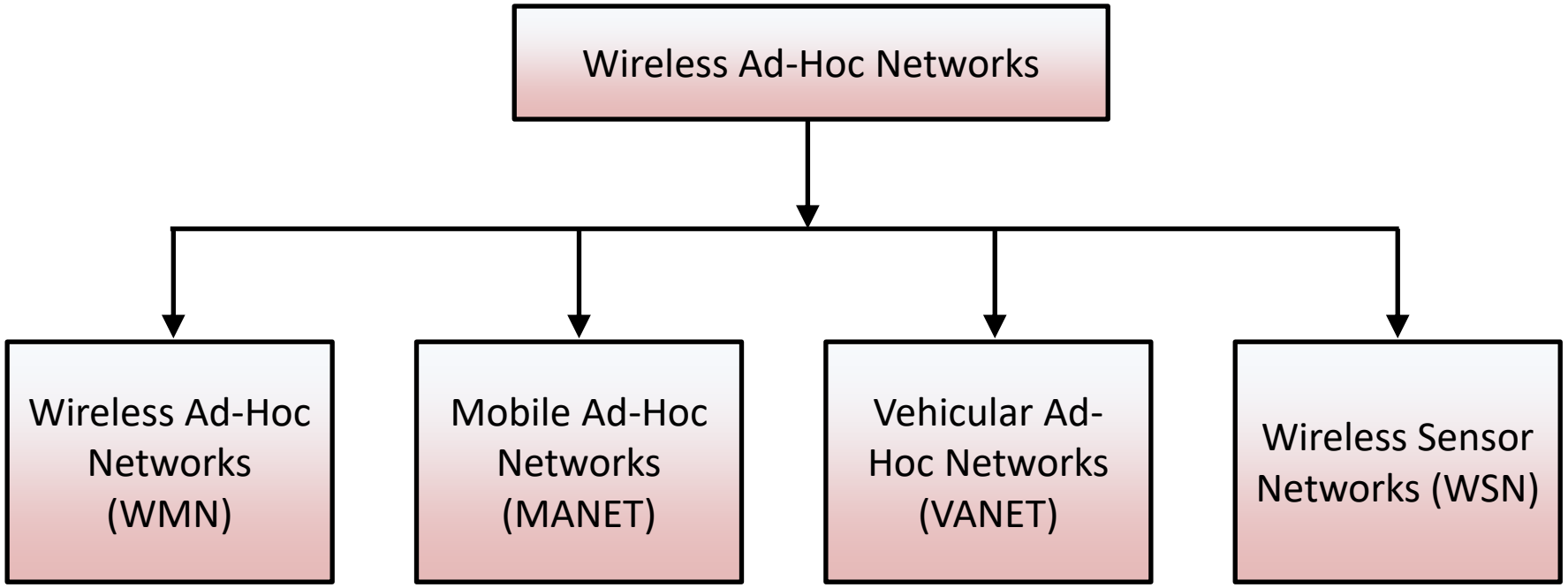
Technology	Application Focus	Data Rate	Range	Configuration	Other features
ZigBee (IEEE 802.15.4)	Home Automation, Smart Grid	Up to 250 Kbps	10m nominal up to 100m	Master Slave (Up to 256 Devices) Peer-to-Peer	Long Battery Life
Bluetooth (IEEE 802.15.1)	Wireless alternative to RS-232 Cables	1 Mbps	100m	8 Active Device Pico net Scatter net	Authentication Encryption
IEEE 802.11 (Ad-Hoc Mode)	Single Hop Ad-hoc Networks	54 Mbps (802.11g)	100-200m	Peer-to -Peer	Inexpensive hardware

Networking Technologies

- Use the one-hop direct communication capabilities provided by underlying enabling technologies to provide end to end reliable communication from sender (one or more) to receiver (one or more) , not in direct communication range
- Functions
  - Routing – Identifying the path from sender to receiver
  - Forwarding – Using the previously identified path to actually forward the packets

  Designing a Routing Protocols for MANETs is one of the main research challenges.
- On top of these, MANETs use Transmission Control Protocol (TCP). But inherent challenges of Ad-Hoc networks make ill-suited for MANETs

Classification of Wireless Ad-Hoc Networks



Types of Ad-Hoc Network (cont.)

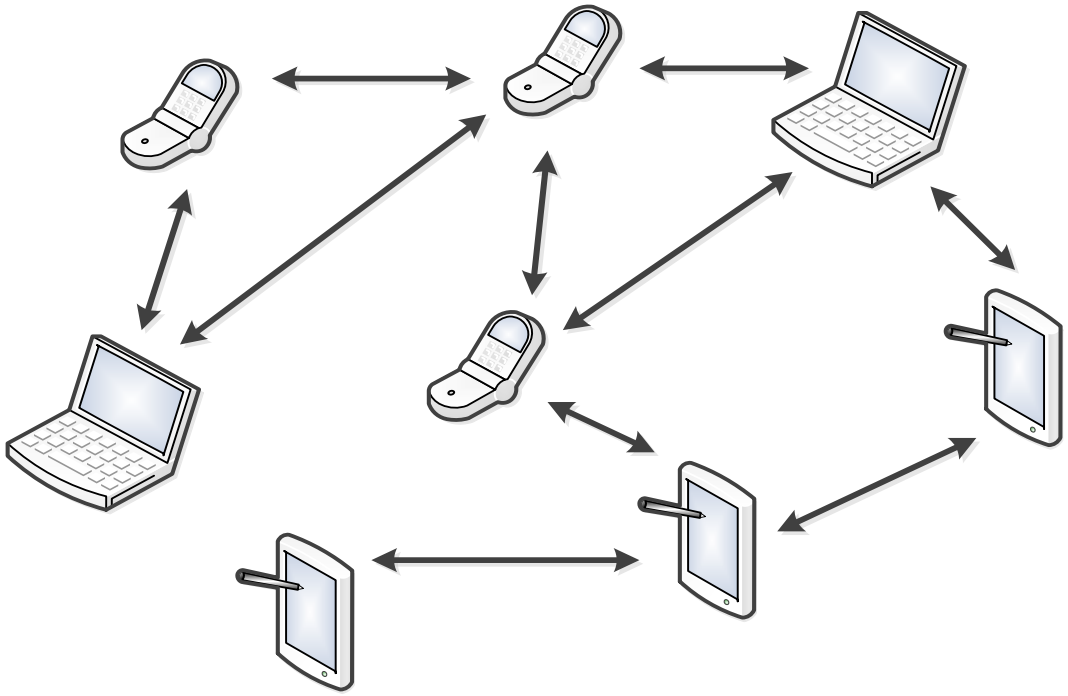


Fig: Mobile Ad-Hoc Network (MANET)

Mobile Ad-Hoc Network

- Infrastructure less network of mobile devices connected wirelessly which follow the self-CHOP properties
  - Self-Configure
  - Self-Heal
  - Self-Optimize
  - Self-Protect
- Highly dynamic topology which frequent link changes
- Nodes act as routers to forward other nodes' packets
- MANETs enable spatial spectrum re-use due to limited bandwidth of each node

Types of Ad-Hoc Network (cont.)

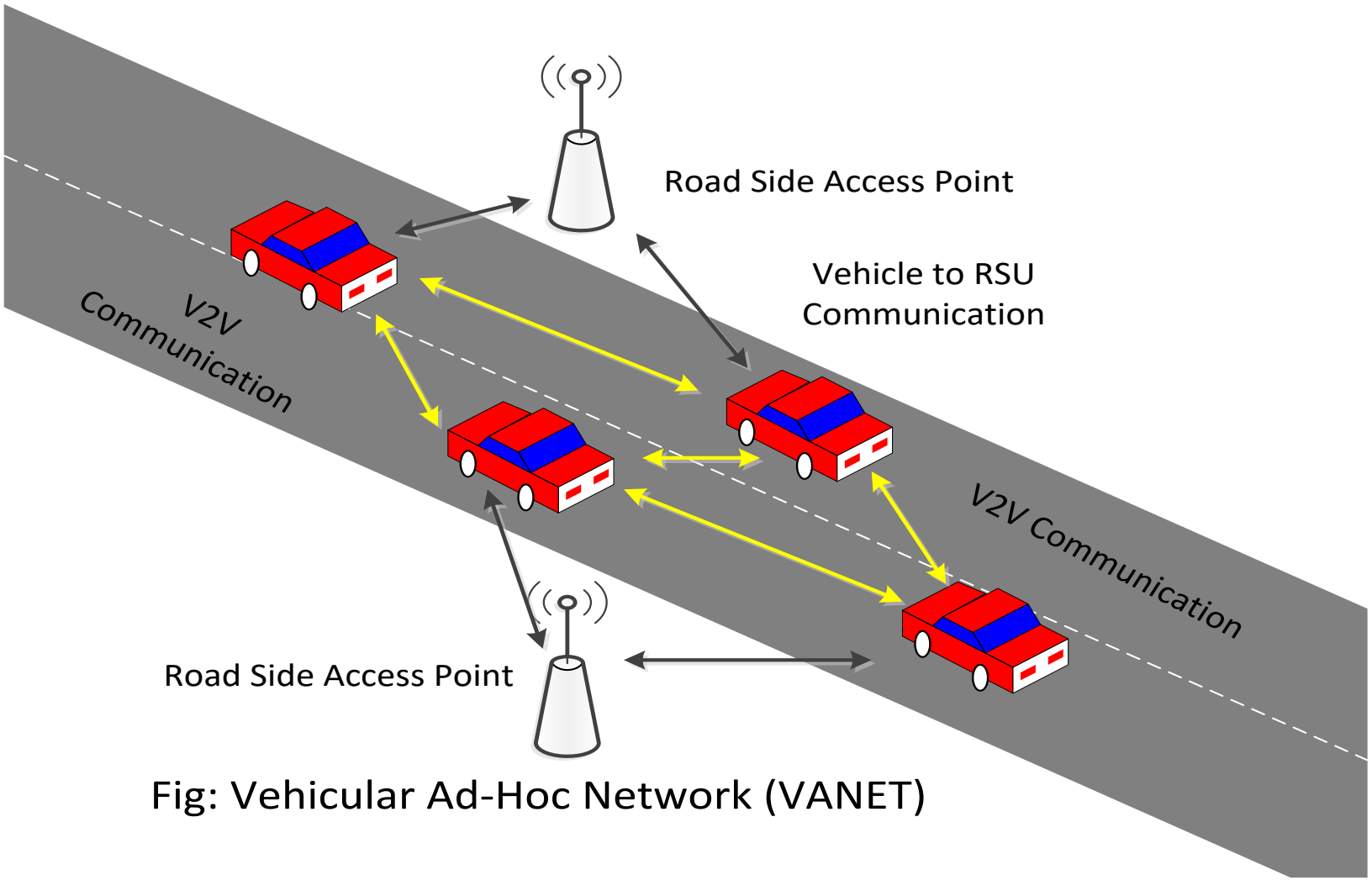


Fig: Vehicular Ad-Hoc Network (VANET)

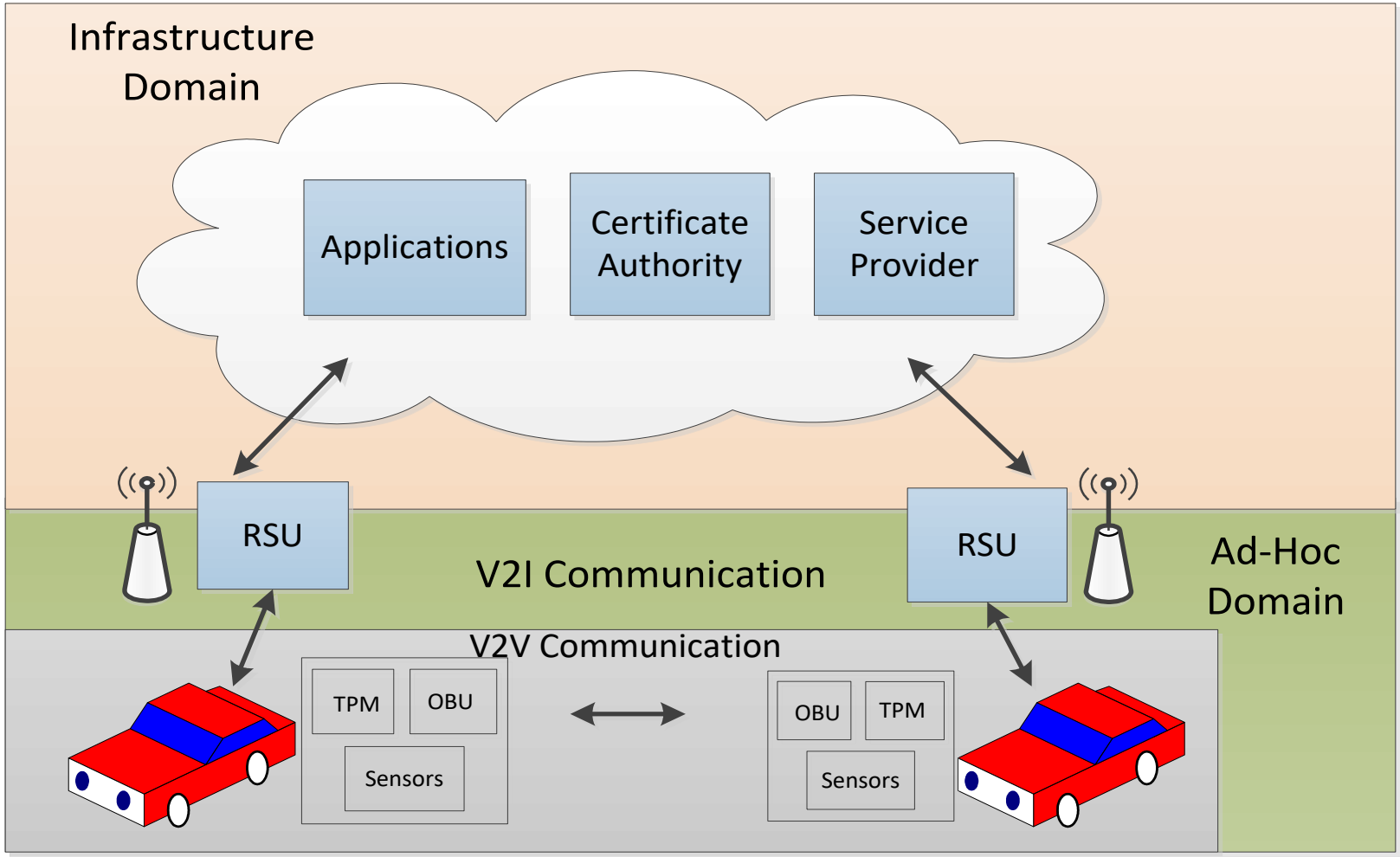
Vehicular Ad-Hoc Networks

- Spontaneous data exchange between vehicles
- Key component of Intelligent Vehicle System (ITS)
- Uses variety of communication technologies
  - Short range technologies like WLAN (Bluetooth or Wi-Fi)
  - Cellular technologies like LTE
- Consists of both inter-vehicle (V2V) communication and vehicle to infrastructure (V2I) communication
- Different than MANET in that they follow predictable patterns e.g. along a road
- Very high mobility, much greater than those found in MANETs

Vehicular Ad-Hoc Networks (cont.)

- Advantages and Applications of VANETs
  - Co-operative Driving
  - Information Sharing and Media Streaming
  - Value added services like Internet Access and Navigation
- Components of VANET
  - On Board Unit (OBU) – Responsible for data collection from different sensors and communication with other OBUs
  - Road Side Unit (RSU) - Infrastructure which enables communication to the outside network
  - Communication Technology – *Wireless Access in Vehicular Environment (WAVE)* supports multi-hop communication between vehicles
    IEEE 1609.2 standard commonly known as DSRC 802.11p

Vehicular Ad-Hoc Networks (cont.)



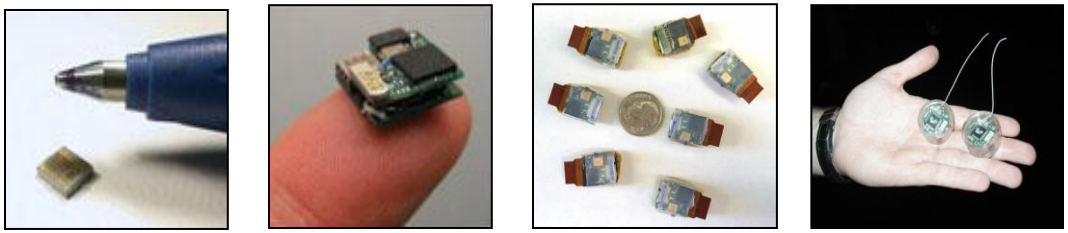
MANET vs VANET

Metric	MANET	VANET
Cost of Deployment	Comparatively cheap	Comparatively high
Mobility Scenario	Low	Very High
Frequency	2.4 GHz (802.11 ad-Hoc)	5.9 GHz (WAVE)
Range	100m	1000m
Partitioning of Network	Low	Frequent
Mode of operation	Infrastructure Less	Both Infrastructure and Infrastructure less
Movement Pattern of Nodes	Random	Constrained by Road

Wireless Sensor Networks

- Consists of a large number of sensor nodes, densely deployed over an area.
- Sensor nodes are capable of collaborating with one another and measuring the condition of their surrounding environments (i.e. light, temperature, sound, vibration).
- The sensed measurements are then transformed into digital signals and processed to reveal some properties of the phenomena around sensors.
- Due to the fact that the sensor nodes in WSN have short radio transmission range, intermediate nodes act as relay nodes to transmit data towards the sink node using a multi-hop path.
- Small size, typically less than a cubic cm and has embedded OS like TinyOS
- Must consume extremely low power
- Should be autonomous i.e. operate on an unattended manner in a highly dense area.
- WSNs can be either mobile or stationary

Sensor Nodes



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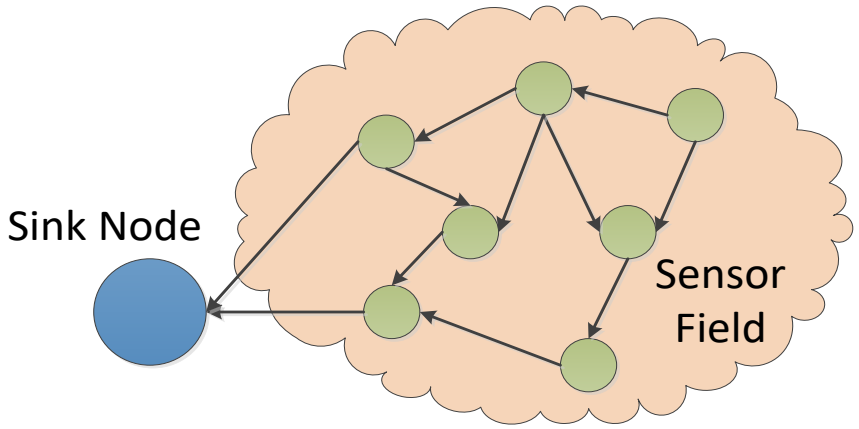
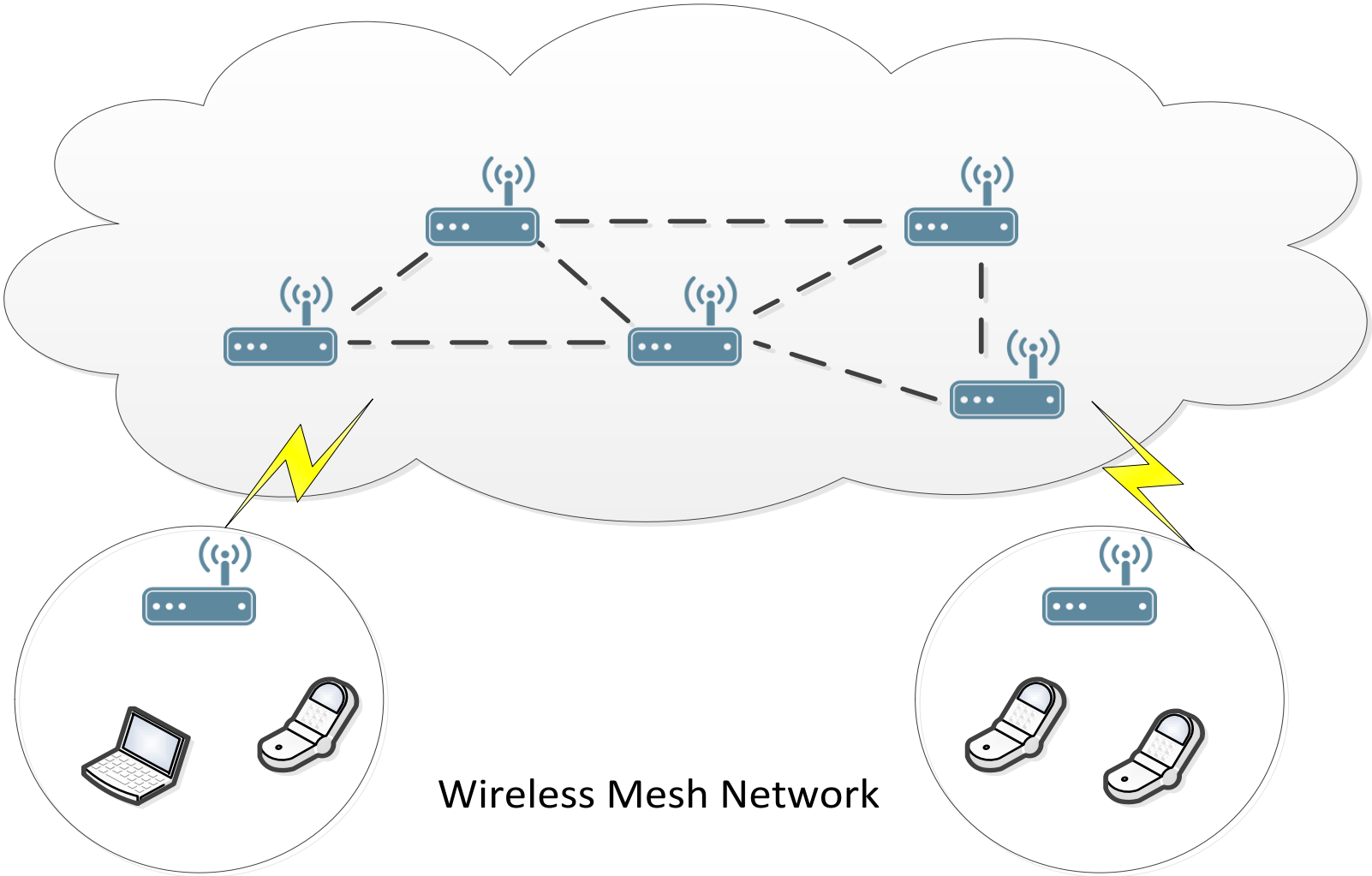
Applications of WSNs include :

- Temperature measurement
- Humidity level
- Lighting condition
- Air pressure
- Soil makeup
- Noise level
- Vibration



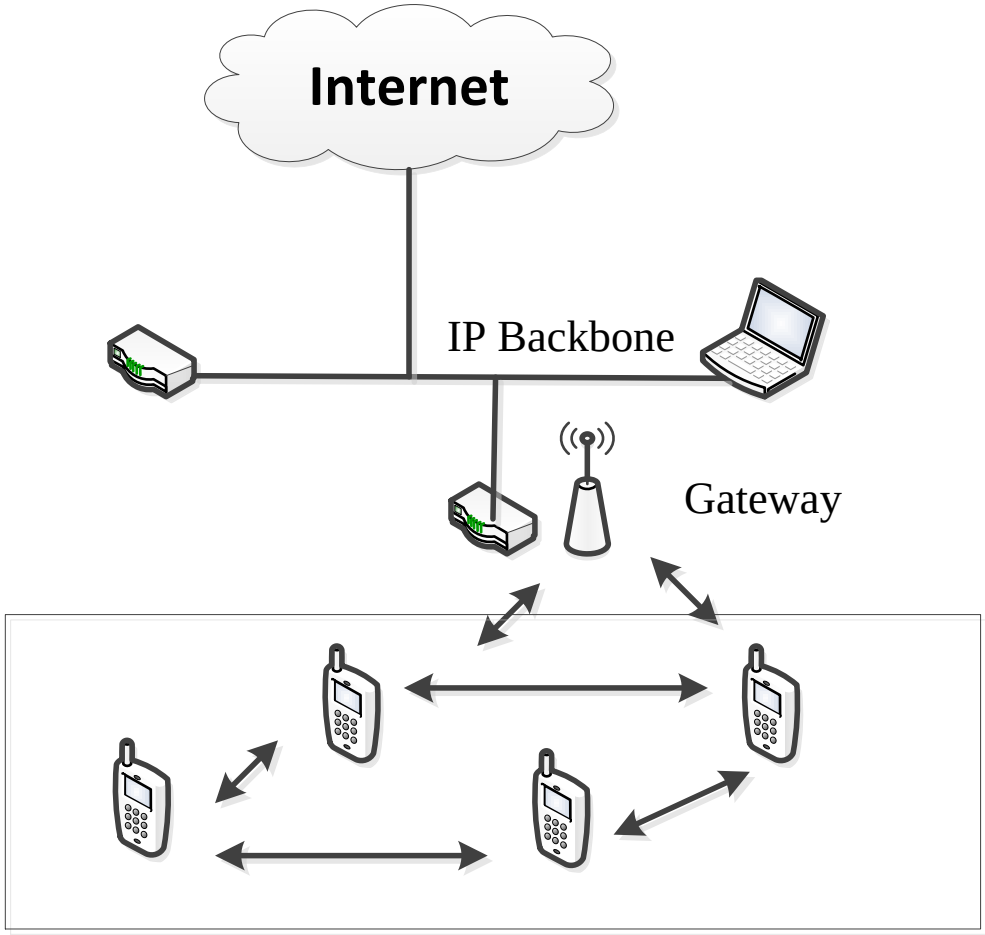
Wireless Mesh Networks



Wireless Mesh Networks (Cont.)

- Composed of mesh routers and mesh clients
- WMNs have multiple redundant links in the network. Upon link failure traffic is routed through alternate links. This increases robustness of the network
- Mesh routers can have same coverage range as a traditional router but with less transmission power through multi-hop communication
- Integration and Interoperation with older legacy networks can be easily achieved since WMNs are IP based.
- Application scenarios include Broadband Home Networking, Enterprise networking, Metropolitan Area Networks, Building Automation, Transportation Systems etc.

Ad-Hoc Networks & Internet



MANETs connected to the Internet

Constraints in Ad-Hoc Networks

- Infrastructure-less
  - Lack of centralized entity dictates that network management has to be distributed over the network leading to a host of problems
- Dynamically changing Network Topology
  - Unpredictability, frequent route changes and packet losses
- Physical Layer Limitation
  - Radios use generally used in broadcast mode and are limited in power and range. This leads to issues like hidden and exposed problems.
- Limited Link Bandwidth
  - Nodes communicate with each other over bandwidth constrained and error prone channel which causes delay and congestion issues at the nodes to be much more pronounced.

Common Challenges

- Scalability
  - Providing acceptable levels of service in the presence of large number of nodes.
  - Typically, throughput decreases at a rate of $\sqrt{N}$, where *N* = number of nodes.
- Quality of Service
  - Offering guarantees in terms of bandwidth, delay, jitter, packet loss probability.
  - Limited bandwidth, unpredictable changes in RF channel characteristics.
- Energy Efficiency
  - Nodes have limited battery power
  - Nodes need to cooperate with other nodes for relaying their information.
- Security
  - Open medium.
  - Nodes prone to malicious attacks, infiltration, eavesdropping, interference.

Device Heterogeneity

- Heterogeneous mobility devices
  - Palm pilot, laptop, tablet PC, mobile phone, etc.
- Differences in powerfulness and capacity of devices.
  - Different storage and processing power.
  - Different battery power, lifetime.
- Cooperation in forwarding packets
  - Differential dissipation of limited energy by devices.
- Problems further complicated.

End of Module I

Thank you!