Wireless Mesh Networks

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Lecture № 10

Outline

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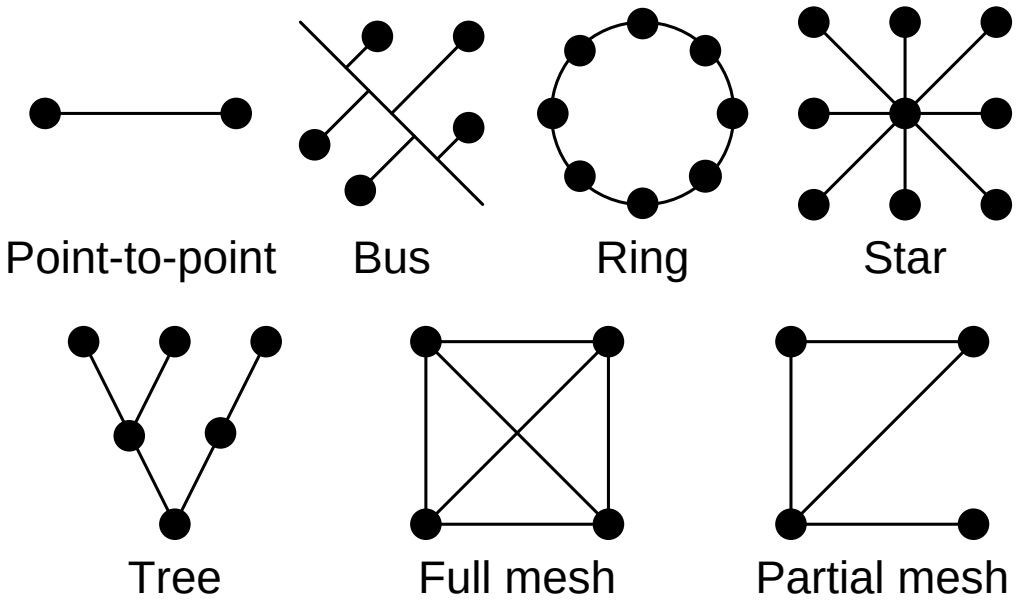
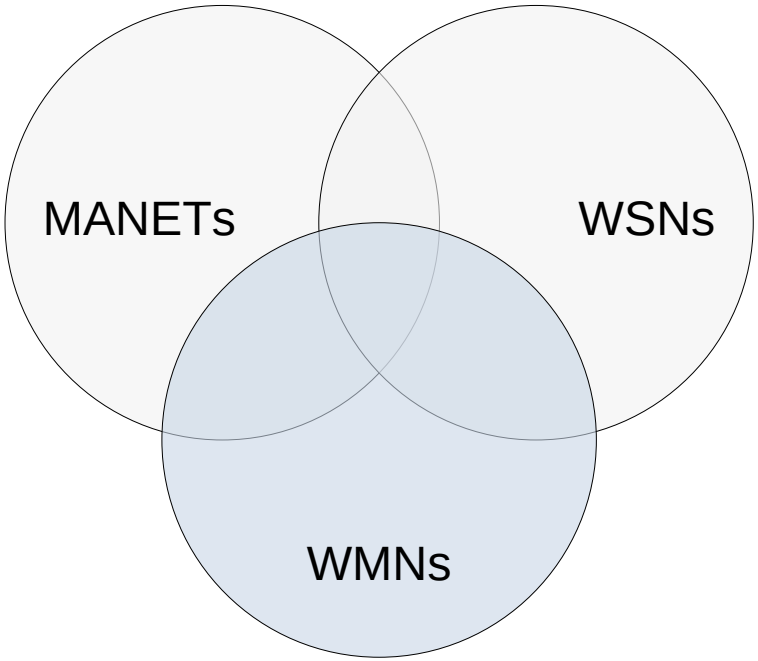
Introduction

- **Wireless Mesh Networks (WMNs)** – networks made up of wireless nodes organized in a **mesh topology**
- Unlike mesh and ring, the other topologies do not offer alternative routes through the network
  - To maximize performance and reliability, each node should have at least 2 neighbors
  - However, full mesh is often impractical or impossible



Introduction (cont'd)

- **3 types of multihop wireless networks**:
  - Wireless Mesh Networks (WMNs)
  - Wireless Sensor Networks (WSNs)
  - Wireless ad hoc networks (aka **mobile ad hoc networks, MANETs**)



Introduction (cont'd)

- **Wireless Mesh Networks (WMNs)** – use multihop wireless relaying over a partial mesh topology for its communication
- **Wireless Sensor Networks (WSNs)** – formed by spatially distributed autonomous sensors that can gather physical parameters and transmit them to a central monitoring node
- **Wireless ad hoc networks (MANETs)** – mainly infrastructureless networks with highly dynamic topology
  - *ad hoc* (Latin) – 1) for a particular purpose only; 2) **arbitrary**
  - In networking, 'ad hoc' refers to a system of network elements that combine to form a network requiring little or no planning

Introduction (cont'd)

Feature	**Wireless ad hoc networks**	**Wireless mesh networks**
Topology	Highly dynamic	Relatively static
Mobility of relay nodes	Medium to high	Static to low
Energy constraint	High	Low
Infrastructure	Infrastructureless	Partial or fully fixed
Relaying	By mobile nodes	By fixed nodes
Deployment	Easy to deploy	Some planning required
Traffic	Typically user traffic	User and sensor traffic
Popular application scenario	Tactical communications	Tactical and civilian communications

Introduction (cont'd)

- **Benefits** of WMNs:
- **Increased reliability**
  - In WMNs, the wireless mesh routers provide **redundant paths** between the sender and the receiver
  - This eliminates single point failures and potential bottleneck links
  - Network robustness against potential problems (e.g., node failures, and path failures due to RF interferences or obstacles) can also be ensured by the existence of multiple possible **alternative routes**
- **Low installation costs**
  - Recently, the main effort to provide cheap wireless connectivity is through the deployment of infrastructure WLANs
  - To assure almost full coverage in a large area, it is required to deploy a large number of access points (APs), resulting in high expenses
  - Constructing a WMN decreases the infrastructure costs, since it requires only a few points of connection to the wired network

Introduction (cont'd)

- **Large coverage area**
  - Although the data rates of modern WLANs are increasing, for a specific transmission power, the coverage and connectivity of WLANs decreases as the end-user becomes further from the AP
  - Multihop and multichannel communications among mesh routers can enable long-distance communication without significant performance degradation
- **Self-(re)configuration and scalability**
  - I.e., mesh clients and routers automatically establish and maintain network connectivity
  - E.g., when new nodes are added into a WMN, these nodes utilize their meshing functionalities to automatically discover all possible routers and determine the optimal paths to the wired Internet
  - The existing mesh routers reorganize the network considering the newly available routes, so the network can be easily expanded

Introduction (cont'd)

- **3 types of WMN nodes**:
  - **Mesh clients** – end-user devices (PCs, laptops, smartphones, etc.)
  - **Mesh routers** – small devices with limited processing power and memory, which are often mounted on lamp posts or rooftops
  - **Gateways** (aka **backhaul nodes**) – provide access to the Internet
- Customers can access WMNs using either wireless (e.g., WiFi) or wired (e.g., Ethernet) connections

Introduction (cont'd)

- Each node can operate not only as a host but also as a router, **forwarding** packets on behalf of other nodes that may not be within direct wireless transmission range of their destinations
- Gateways enable the integration of WMNs with various existing wireless networks such as cellular systems, WSNs, WiFi, WiMAX, etc.
- A WMN is dynamically **self-organized** and **self-configured**, with the nodes in the network automatically establishing and maintaining mesh connectivity among themselves
  - Creating, in effect, an ad hoc network
  - WMNs share many similar features with P2P networks

Outline

WMN Architectures

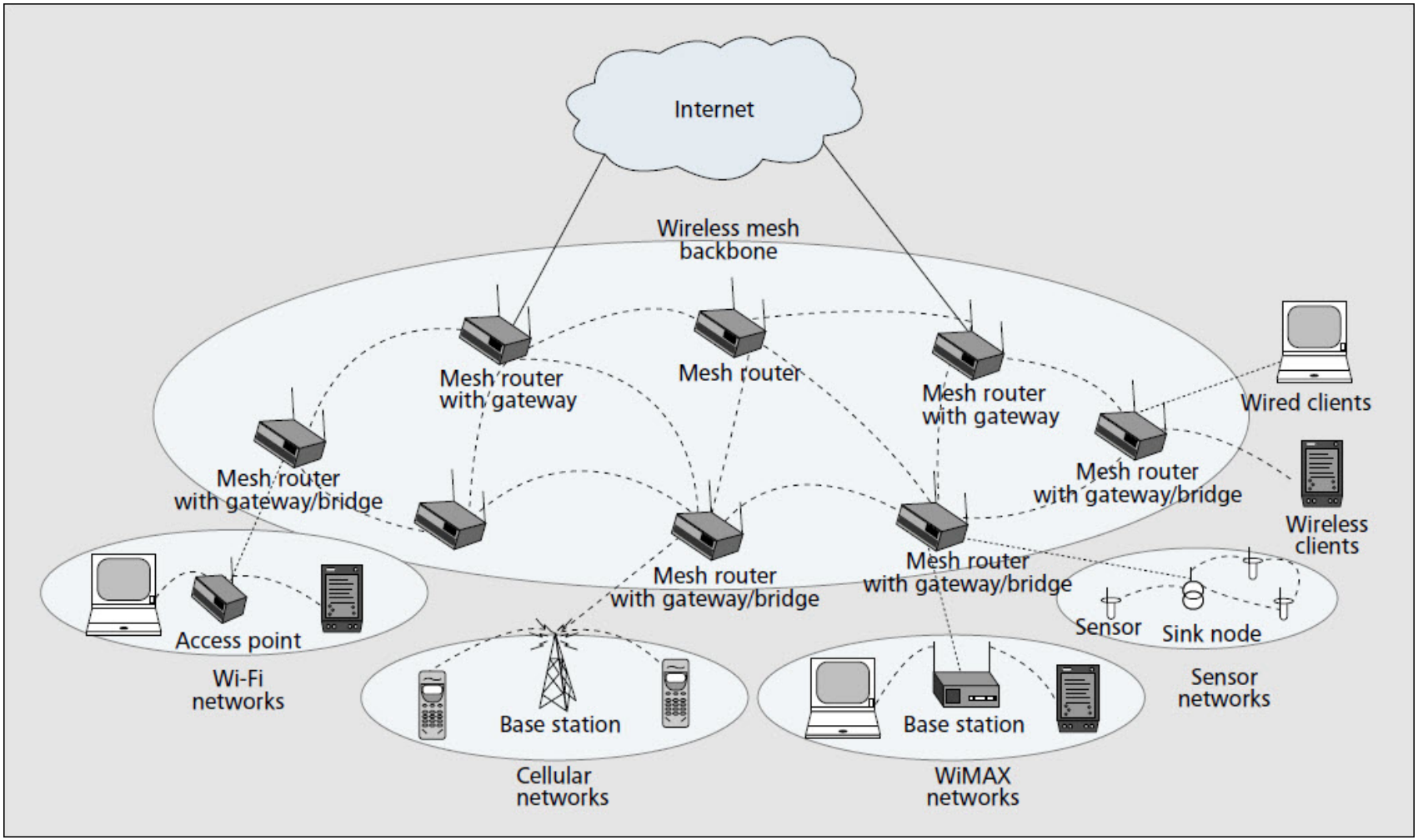
- **3 types of WMN architectures** :
  - Flat
  - Hierarchical
  - Hybrid
- **Flat WMN** (aka **client WMN**) – the network is formed by end-user devices that act as both mesh clients and mesh routers
  - This approach (aka **client meshing**) provides P2P networking among client devices and is closest to a MANET
  - Flat WMNs are usually formed using one type of radio on devices
- **Benefits** of flat WMNs:
  - Simplicity
- **Shortcomings** of flat WMNs:
  - Lack of network scalability and high resource constraints

WMN Architectures (cont'd)

- **Hierarchical WMN** (aka **infrastructure/backbone WMN**) – the network has 2 levels in which mesh clients form the lowest level and communicate with the WMN backbone formed by mesh routers
  - This approach (aka **infrastructure meshing**) provides a backbone for conventional clients and enables integration of WMNs with existing wireless networks, through gateway/bridge functionalities in mesh routers
  - In most cases, mesh routers are dedicated nodes and do not originate or terminate data traffic like mesh clients

WMN Architectures (cont'd)

- Hierarchical WMN

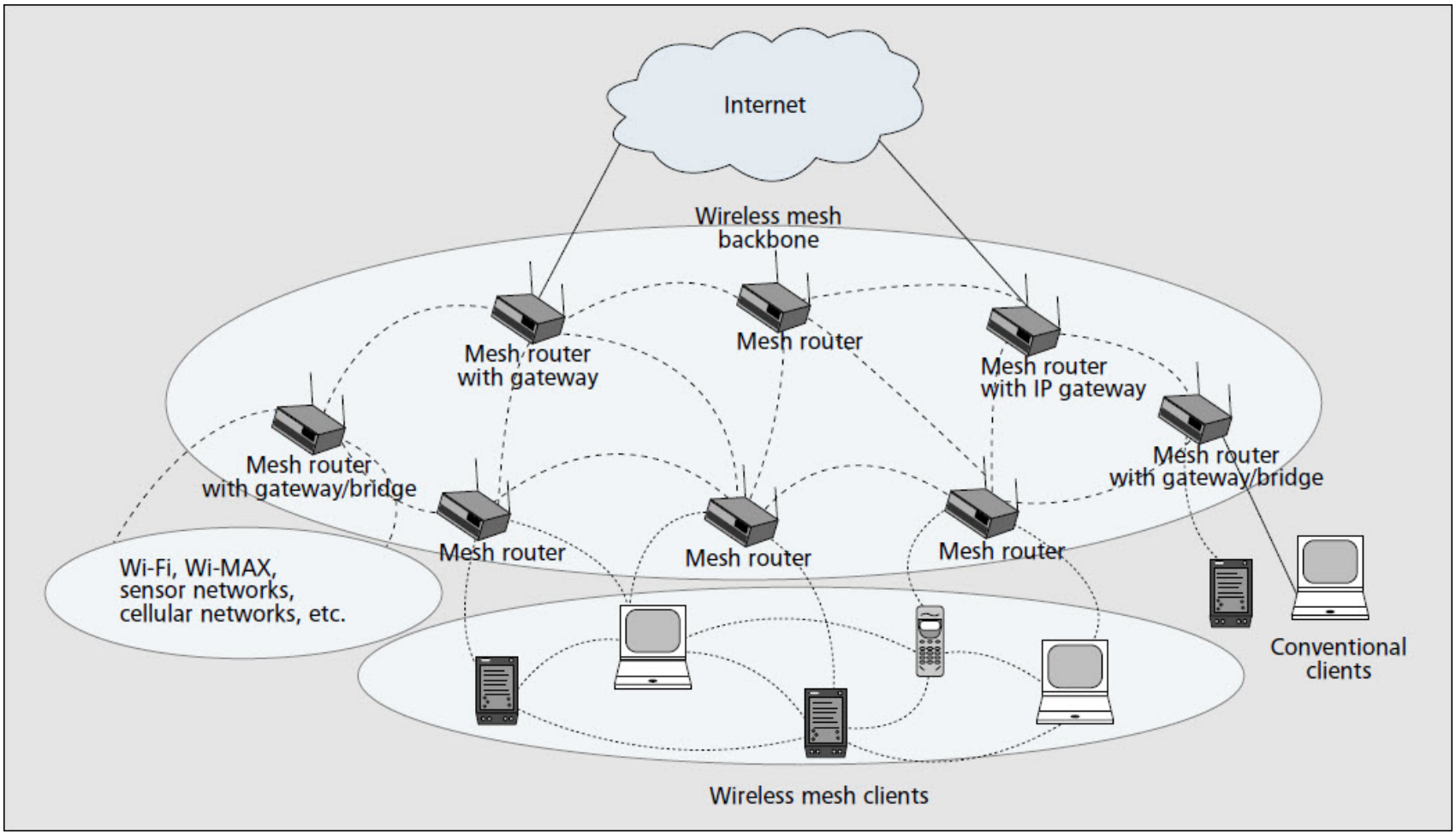


WMN Architectures (cont'd)

- **Hybrid WMN** – a combination of client and infrastructure meshing
  - Mesh clients can access the network through mesh routers as well as directly meshing with other mesh clients
  - While the infrastructure provides connectivity to other networks, the routing capabilities of mesh clients provide improved connectivity and coverage inside the WMN

WMN Architectures (cont'd)

- Hybrid WMN



Outline

WMN Application Areas

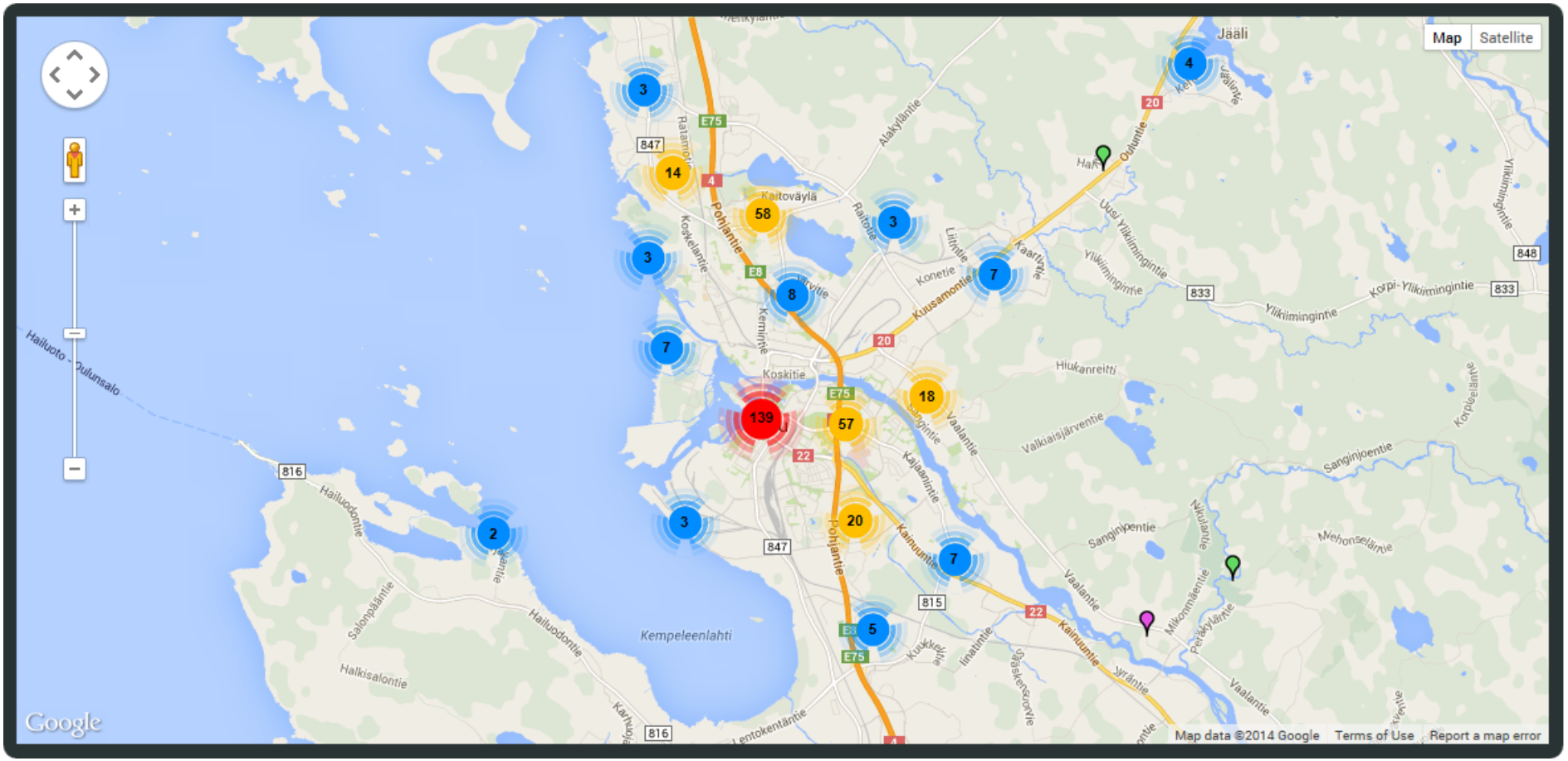
- As a rule, WMNs are superior in environments that match 1 or more of the following criteria:
  - The coverage area is extensive, either within a large building or spanning a large geographical area
  - Coverage is required both indoors and outdoors
  - The coverage area is unwired or under-wired
  - Existing 'line of site' obstructions can be bypassed with 1 or 2 hops
  - The installation must be done quickly and/or has a limited lifecycle

WMN Application Areas (cont'd)

- **Applications and industries that are well-suited to WMNs**:
  - Hospitality and entertainment (hotels, casinos, museums, etc.)
  - Warehousing and manufacturing (warehouses, factories)
  - Transportation and shipping (for logistics, security, surveillance, etc.)
  - Retail (shopping centers)
  - Public Internet access (HotSpots)
  - Metropolitan and community-wide networks (e.g., www.panoulu.net)
  - Public safety and first responders (for police, fire departments, etc.)
  - Broadband home networking (to replace APs by wireless mesh routers)
  - Educational institutions (schools and university campuses)
  - Health care (hospitals)

WMN Application Areas (cont'd)

- The public access network in Oulu (panOULU): AP map



Outline

Critical Design Factors

- **Critical factors influencing the performance of WMNs**:
- **Radio techniques**
  - Directional antennas
  - MultiInput/MultiOutput (MIMO) systems
  - Multi-channel systems
  - Cognitive radio
- **Scalability**
  - Transport protocols
  - Routing protocols
  - MAC protocols

Critical Design Factors (cont'd)

- **Mesh connectivity**
  - Topology-aware MAC protocols
  - Topology-aware routing protocols
- **Broadband and QoS**
  - End-to-end transmission delay
  - Delay jitter
  - Packet loss rate
  - Fairness
  - Throughput
  - Differentiated services

Critical Design Factors (cont'd)

- **Security**
  - Key distribution
  - Secure MAC and routing protocols
  - Intrusion detection and security monitoring
- **Ease of use**
  - Automatic power management
  - Self-organization
  - Dynamic topology control
  - Robustness to temporary link failures
- **Compatibility and interoperability**
  - Support both conventional and mesh clients