Introduction to Wireless Mesh Networks

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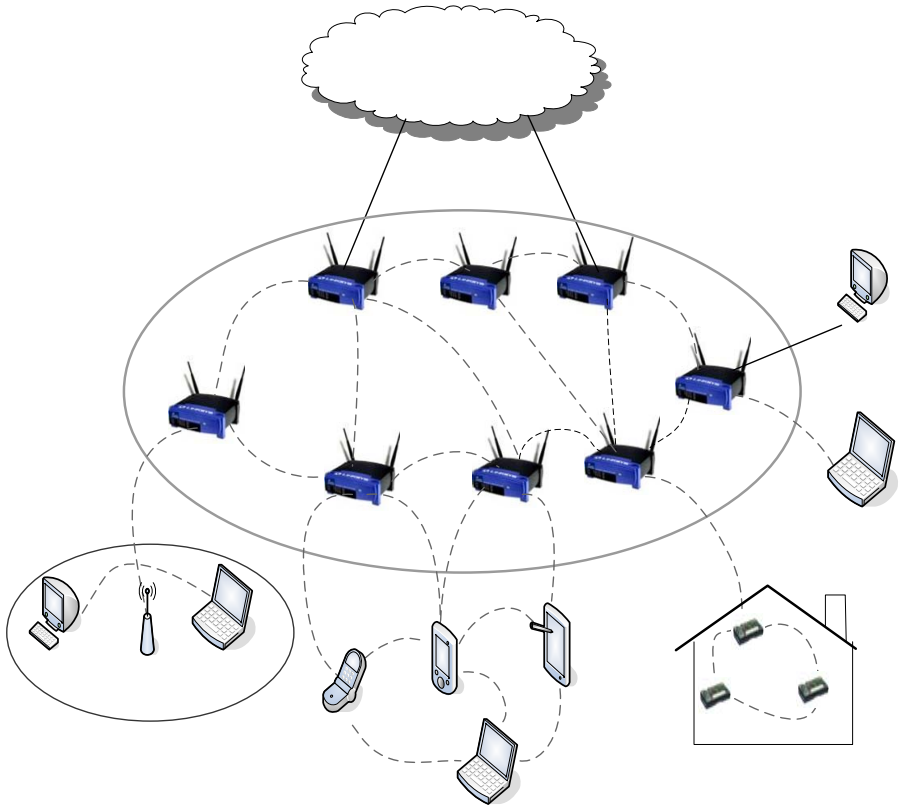
Wireless Mesh Networks

- A hybrid network, built on a mix of fixed and mobile nodes interconnected via wireless links
  - A fully wireless network that employs multihop communications to forward traffic en route to/from wired Internet entry points.
- A commercial extension of mobile ad hoc networks
  - Envisioned as the economically viable networking paradigm to build up broadband and large-scale wireless commodity networks.

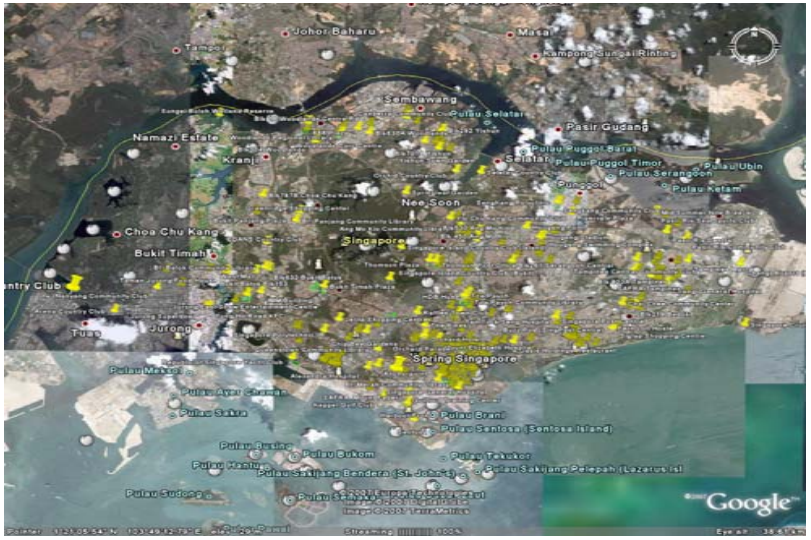


Why Wireless Mesh?

- Low up-front costs
- Ease of incremental deployment and maintenance
- Provide NLOS coverage
- Highly reliable
- Advantages of Wireless APs (over MANETs)
  - Wireless AP backbone provides connectivity and robustness which is not always achieved with selfish and roaming users in ad-hoc networks
  - Take load off of end-users
  - Stationary APs provide consistent coverage

Applications

- Metro-scale Community Networks
  - U-City, Mobile-City projects
- Campus Networks
- Local Area Networks
  - Hotels, Malls, Parks, Trains, etc.
- Home Networks
  - Coverage extension, Healthcare
- Ad hoc deployment of LAN
  - Public Safety, Rescue & Recovery Operation
- Tactical Wireless Networks
- Public Transportation Systems
  - Vehicle-to-Vehicle, Vehicle-to-Infra
- And more…
  - Logistics, Weather forecast



Wireless hot-spot / hot-zone map in Singapore

Research on WMNs: Topic-wide (1/5)

High-capacity and throughput enhancements

- Multi-channel MAC with Multiple/Single radio(s)
  - Spatial reuse
- Static and dynamic channel/interface assignment
  - Centralized or distributed algorithm
- Multi-channel/radio-aware Routing Protocol
- Power Control
  - To reduce interference and increase SNR
- Advanced Antenna Technologies
  - Smart antenna / MIMO (Multi-Input Multi-Output)

Research on WMNs : Topic-wide (2/5)

Design of Scalable Networking Functions

- Heterogeneous and hierarchical mesh network architecture
- Efficient broadcasting and multicasting
- Routing
  - Multi-path routing for load balancing
  - New routing metrics, such as LQSR (Link Quality Source Routing)
- Cross layer design
  - Routing-MAC
  - Routing-PHY
  - Transport-MAC

Research on WMNs : Topic-wide (3/5)

QoS Provisioning

- To support evolving applications like media streaming and VoIP
- IEEE 802.11e extension for multi-hop mesh environments
  - Multiple queues and priority support
- QoS aware routing and metrics
  - Available bandwidth, average delay, jitter, ...

Research on WMNs : Topic-wide (4/5)

Security

- Authentication, Privacy, and Reliability
- User data protection
  - Client to AP encryption
  - Authentication of APs and Clients to verify each other's identity
  - Current technologies: 802.1x port based network access control, IPSec, Application-level encryption
- Network data protection
  - Secure routing
  - Secure key distribution

Research on WMNs : Topic-wide (5/5)

System-wide Network and Resource Management

- Network auto-configuration
- Network monitoring
- Congestion control
  - Inter-flow vs. intra-flow
- Topology control
- Mobility management and hand-off
  - Fast hand-off is a key technology to support multimedia application (e.g. VoIP)

Mesh Networking in IEEE Standardizations

- Several IEEE WGs are actively working to provide wireless mesh networking extensions to their standards.
  - IEEE 802.15.5 – WPAN Mesh
  - IEEE 802.16a/j – WMAN Mesh
  - IEEE 802.11s – WLAN Mesh

IEEE 802.11s – WLAN Mesh

Motivation of WLAN Mesh standards

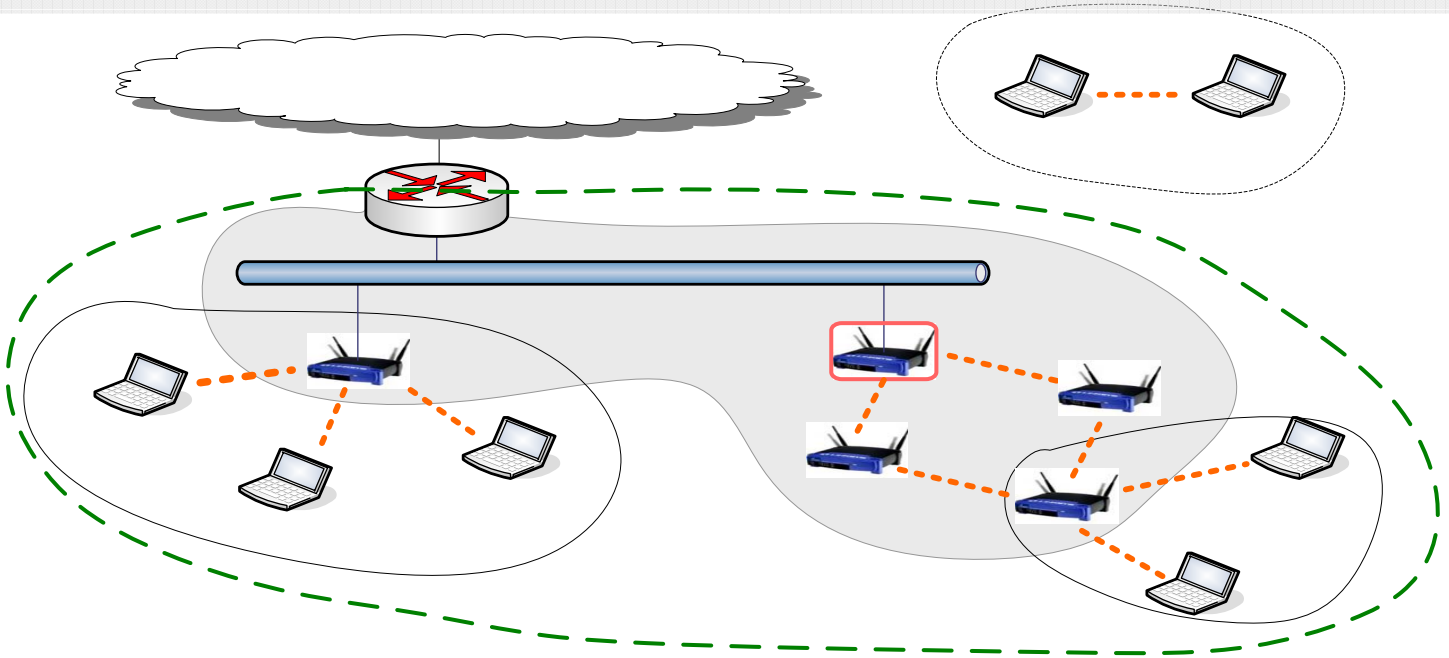
- Current 802.11 ad hoc mode is not sufficient for multi-hop, mesh.
- Recent efforts for the advance of 802.11 standards are still limited due to their inherent dependency upon the wired infrastructure backbones and the last, single-hop communication.

IEEE 802.11 TG “s”

- To design mesh networks consisting of different WLAN devices performing routing at link layer (layer 2)
- To be based on extensions to the current IEEE 802.11 architecture and protocols
- Specifically, to define an extended service set (ESS) mesh
- Recently, draft version 1.02 was released. (March 29, 2007)

IEEE 802.11s – *Architectural Model*

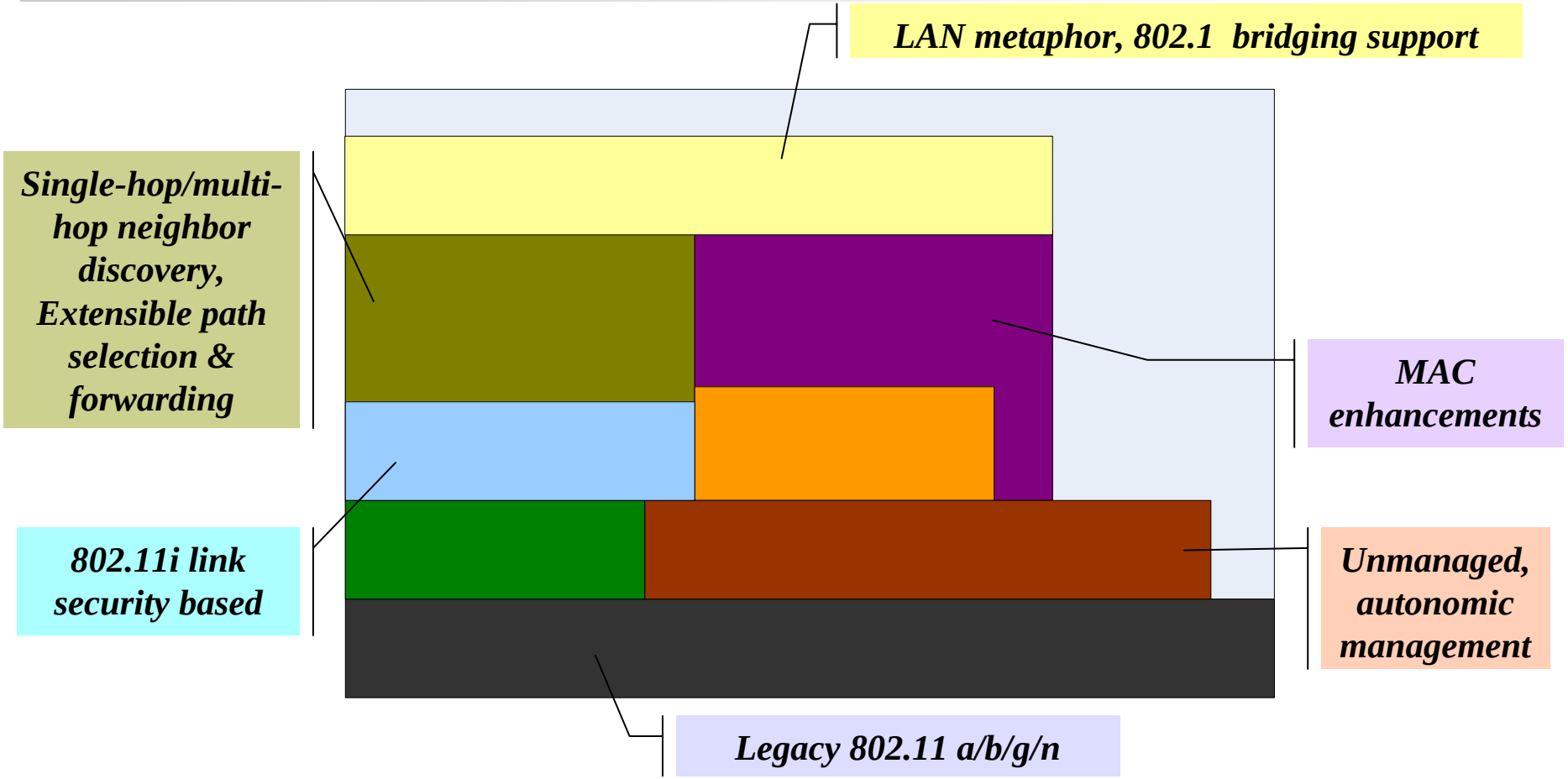
Targeted at unmanaged WLAN Mesh networks and at enabling interoperability with low complexity.



Internal L2 behavior of WLAN Mesh is transparent to higher layers

IEEE 802.11s – *Functional Requirements*

The set of services provided by the WLAN Mesh that support the control, management, and other operation, including the transport of MSDUs between MPs within the WLAN Mesh.



IEEE 802.11s – *Key Functionalities* (1/2)

Mesh Topology Creation

- Self-configuring neighbor discovery
- Channel selection
- Link establishment with neighbor MPs (Authentication/Association)

L2 Routing

- Mesh path selection and forwarding at the link layer
- Radio-aware metrics for routing (e.g., Airtime link metric function)
- Hybrid wireless mesh protocol
  - On-demand Path Selection Mode (RM-AODV)
  - Proactive Tree Building Mode

IEEE 802.11s – *Key Functionalities* (2/2)

MAC Enhancement

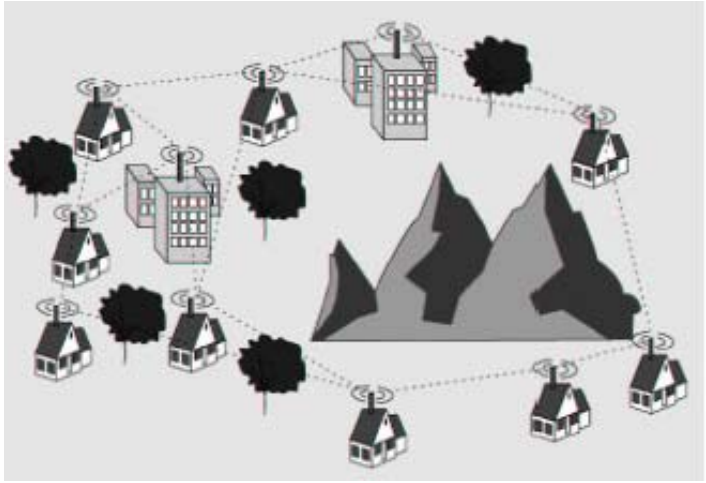
- To support QoS: recommended for use of EDCA in MPs
- To improve network capacity:
  - The usage of multiple channels and multiple radios
  - Efficient handling of the two different kinds of traffic (BSS traffic & Forwarding mesh traffic)
  - Intra-mesh congestion control

Security

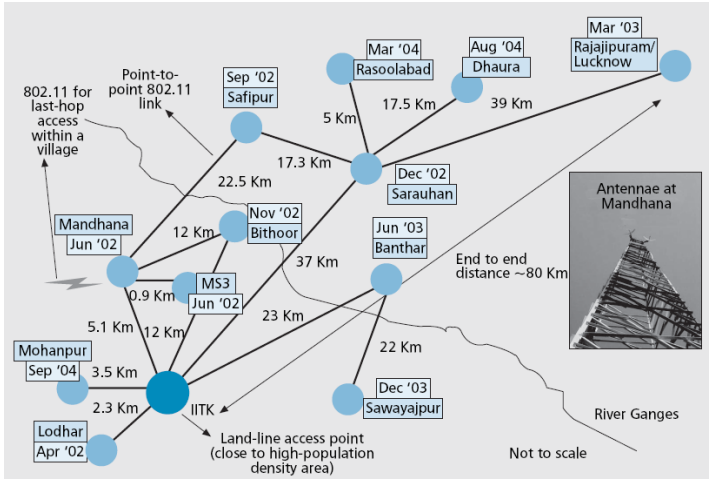
- intends to take advantage of security mechanisms specified in 802.11i (completed in 2004).
- Multi-hop or end-to-end security is required.
- Association/authentication among neighboring MPs/MAPs is needed.

IEEE 802.11s – *Current trends and usage*

- Campus networking: Nortel WMN in National Taiwan University
- Community mesh networks: Cuwin at UIUC, Nokia Rooftop project
- Rural networking: Digital Gangetic Plain in India
- Intelligent Transport System
- Private networks for public safety
- Distribution network in buildings and enterprises etc.



Neighbor hood network



Rural networking

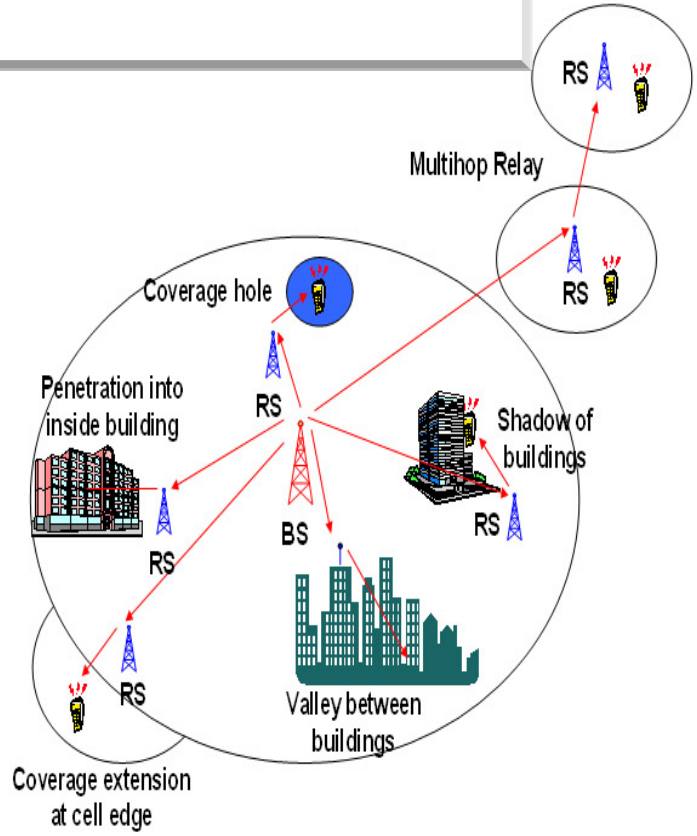
IEEE 802.16j – *WMAN Relay/Mesh*

IEEE 802.16 TG "j"

- Started in July 2005, as the MMR (Mobile Multihop Relay) SG
- Preliminary draft was released in Dec. 2006

Scope

- Support OFDMA PHY mode
- MAC enhancements to 802.16
- To enable the operations of a new base station (MMR-BS) & RS
- Backward compatible to PMP mode (unlike 802.16a/e Mesh mode)



IEEE 802.15.5 – WPAN Mesh

IEEE 802.15 TG“5”

- Established in 2004, considering both low-rate and high-rate WPAN (i.e., 802.15.3 and 802.15.4, respectively)
- In July 2006, they released a recommended practice document for WPAN mesh.

Proposed usage cases

- Low-rate applications
- Sensor networks, like ZigBee
- Control and maintenance networks
- High-rate applications
- Wireless streaming services for consumer electronics
- Interactive delay-sensitive applications, like online gaming

ZigBee Mesh Networks

ZigBee Wireless Mesh

- Based on the peer-to-peer communication supported in IEEE 802.15.4, the ZigBee network can create Wireless Mesh Topology
- ZigBee aims to create general-purpose, inexpensive, and self-organizing mesh networks
- Focused on low-rate embedded devices such as sensors

ZigBee Stack Profiles

- ZigBee (2004~2006) – Mainly for home automation and applications
- ZigBee Pro (expected 2007) – For large scale mesh networks such as commercial and industrial control and automation