Evaluation of A Wireless Enterprise Backbone Network Architecture

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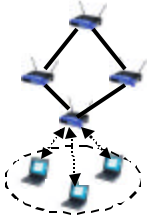
Motivation

Source: BlackHat Briefing 2002

Typical 802.11 deployment

- Wireless *last-hop* (AP — Mobile)
- Wired backbone



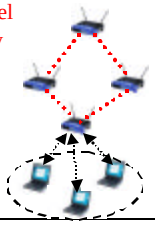
Wireless Mesh Networks

Definition: Network of routers inter-connected by wireless links

- Enterprise backbone connectivity
- Last-mile ISP connectivity

"Multi-hop ad hoc network"

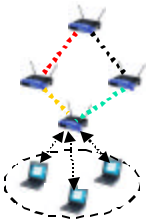
- Single channel
- Low capacity



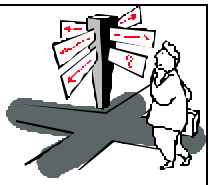
Hyacinth Architecture

Goal: High-capacity wireless mesh network

- Multiple channels
- Commodity 802.11 hardware

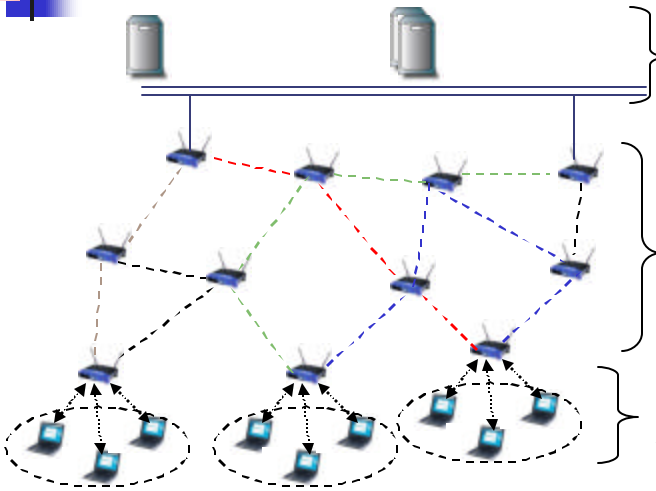


Talk Outline...

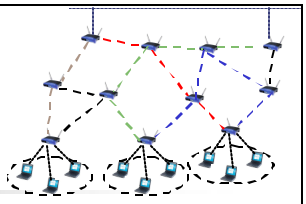


- Background / Motivation
- Proposed Hyacinth Architecture
- Research Issues
- Algorithms
  - *Load-balancing Routing*
  - *Load-aware Channel Assignment*
- Evaluation
- Related Works
- Summary / On-going Research

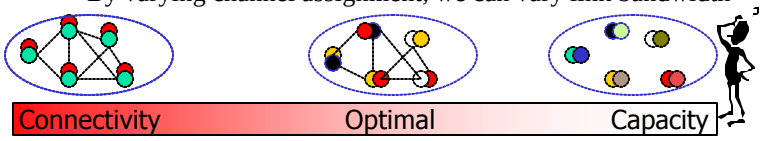
Hyacinth Architecture



Research Issues



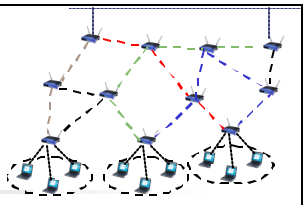
- *Channel Assignment*
  - Channel assignment => Bandwidth of virtual links
  - By varying channel assignment, we can vary link bandwidth



- *Routing*
  - Most traffic directed to/from gateway nodes
  - Routing => Traffic load on virtual links and gateways
  - Goal – Balance the load throughout the network

Optimize "network goodput": Total usable b/w between APs & gateways

Load-balancing Routing



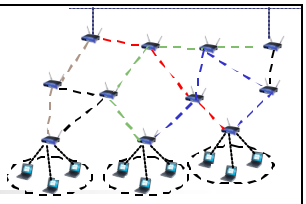
Routing (=Gateway Discovery)

- Similar to 802.1D {spanning-tree protocol}
- Nodes advertise reachability to gateways
- Each node discovers routes to one or more gateways
- One gateway case => forest of trees rooted at gateways

Routing Metric

1. Hop-count [to gateway]
   +static, stable, - imbalance
2. Gateway link capacity [*both* wired and wireless]
   +balanced, +adapts to traffic, - route flaps
3. Path capacity [*i.e.* residual capacity of bottleneck link]
   +handles non gateway bottlenecks

Load-aware Channel Assignment



(1)Neighbor-to-interface

- *X* UP-NICs, *Y* DOWN-NICs, and one CONTROL-NIC
- Typically, *X*=*Y*. For gateways, *X*=0
- DOWN-NICs: load-balanced child nodes association
- UP-NICs: only one parent..

(2)Interface-to-channel

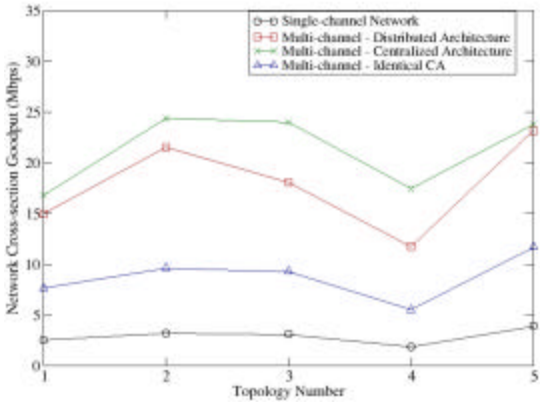
- Exchange channel-usage map with neighbors
- DOWN-NIC: Least-used channel, if it balances channel load
- UP-NIC: same chnl as parent's DOWN-NIC
- CONTROL-NIC: global CONTROL channel
- Adapt channel assignment to traffic patterns

Channel Load Metric

- Contention group size
- Aggregated channel usage
- Combined..

Evaluation

Overall Performance Gains



- Parameters: 60 nodes random topology with 4 gateway nodes.
- 3 NICs/node, 12 channels

- Baseline: Single-channel network
- Identical CA: 3x improvement
- Distributed CA: 6-7x improvement
- Centralized greedy CA: 7-8x
- Multiplexing CTRL with DATA

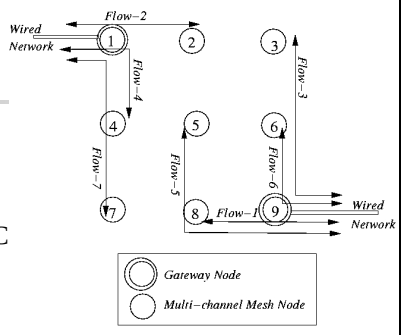
Evaluation
Resources

- *Radio Channels –*
  - Accommodates different number of available channels
  - Saturates at 6 channels with 2 data NICs / node
- *Interfaces –*
  - More NICs help better utilize channel diversity
  - Saturates at 12 channels with 4 data NICs /node
- *Gateways –*
  - Almost linear increase in throughput
- *Placement of Gateways –*
  - Concentrated placement works well
  - More economical

Evaluation
Metrics

- *Routing Metric –*
  - `hop_count` worst, imbalance across gateways
  - `gateway_capacity` ~ `path_capacity`
  - In a real network, any link can form bottleneck
- *Channel Load Metric –*
  - `group_size` worst, imbalance across channels
  - `aggr_usage` better estimates channel load
  - We use combined metric

Evaluation
Testbed



Configuration –
- 9 Win XP desktops, 2 gateway nodes
- Two 802.11a NICs, One 802.11b NIC

FTP Throughput –
- 5-times improvement
- Should be more for larger testbed

Fail-over –
- Node 6 fails; Node 3 switches to Node 2
- < 700 msec to recover
  - 150 msec for failure-detection
  - 1 msec for failure-message propagation
  - ~450 msec for changing route tables
- Additional 50-100 msec for channel switching

Related Works

- *Multi-channel MAC*
  - Packet-by-packet channel switching*[Vaidya][..]*
- *Multi-NIC*
  - Identical channel assignment *[MSR]*
  - Different radio / neighbor *[BelAir]*
  - Beamforming antennas with new MAC *[TAP]*
- *Multi-hop routing*
  - Coordinated load-balancing routing *[Kung]*
  - Load-balancing routing metrics*[Gerla][Zhou]*

Conclusions..

- IEEE 802.11 beyond AP—mobile
- Multi-channel wireless mesh backbone
- Multiple commodity cards per node
- Load-aware channel assignment
- Load-balancing routing
- What's next ?
  - *Mobility:* Device-transparent handoff
  - *Transport:* Link-aware transport protocol
  - *Security:* Secure routing, DoS detection
  - *QoS:* Automatic QoS to interactive flows

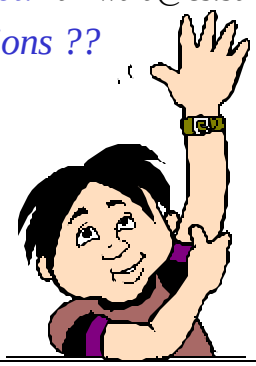
More info..

Project Page: http://www.ecsl.cs.sunysb.edu/multichannel

Google Search: "multi-channel mesh"

Contact: raniwala@cs.sunysb.edu

Questions ??



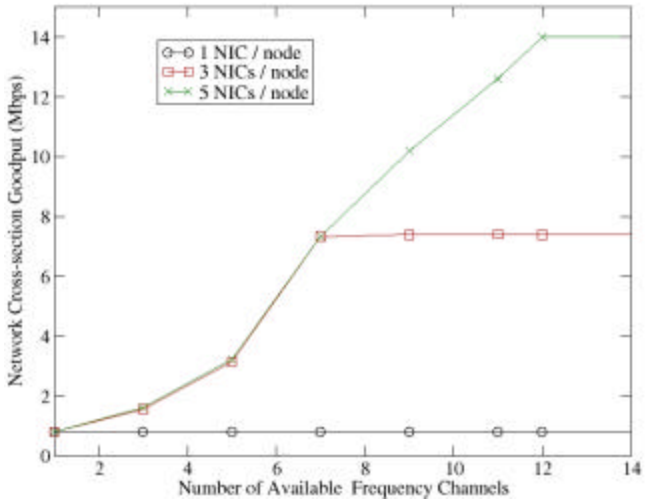
Centralized CA/Routing

- NP-hard problem [multiple subset-sum]
- Greedy technique
- Visit all edges in order of load (highest first)
- Assign locally optimal channel
- Maintain constraints

- Iterate over channel assignment & routing

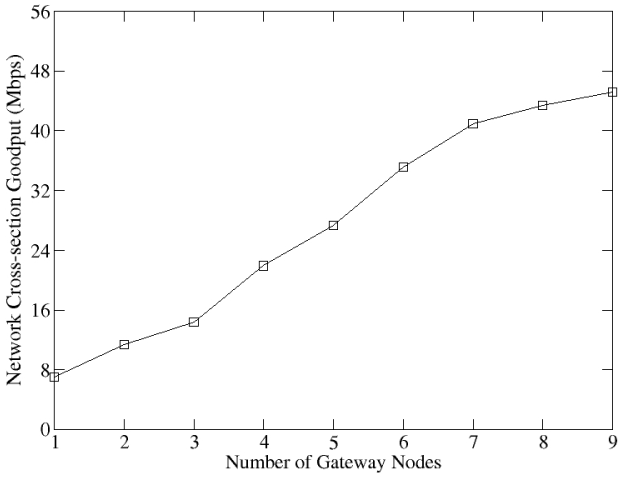
Evaluation

Resources – Interfaces/Channels



Evaluation

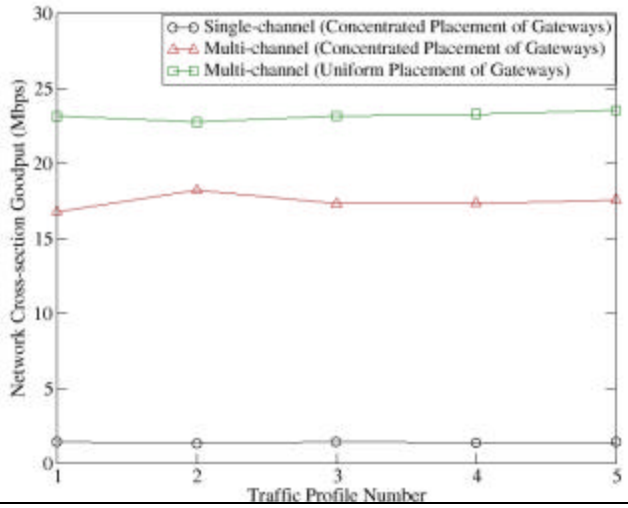
Resources – Gateways



Evaluation
1) Gains
2) Resources
3) Metrics
4) Testbed

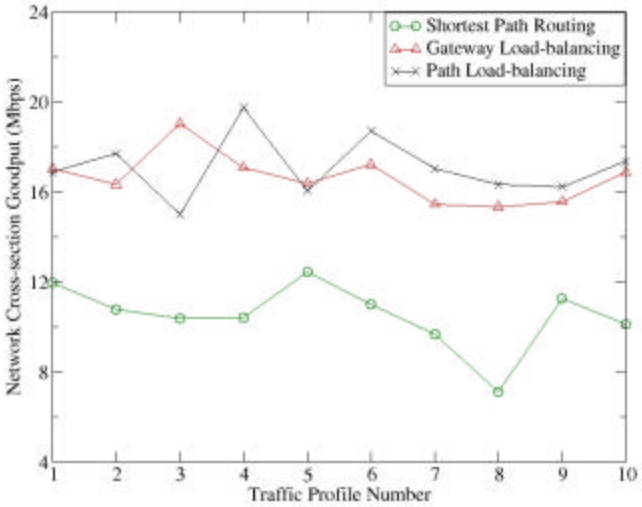
Evaluation

Resources – Gateways' Placement



Evaluation

Metric – Routing



Evaluation
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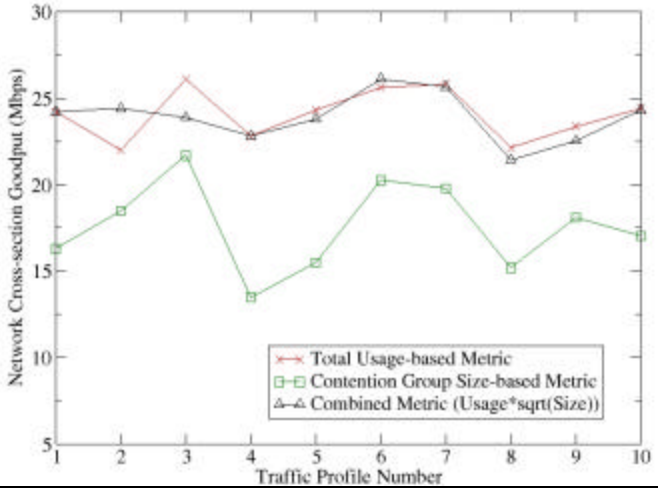
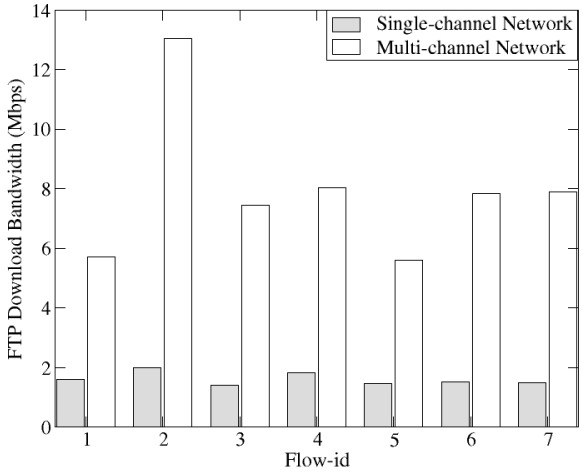
Evaluation

Metric – Channel Load



Evaluation

Testbed – FTP Throughput



Evaluation

Testbed – Fail-over