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Resource-aware Video Multicasting via Access Gateways in Wireless Mesh Networks

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Outline

- The High Level Problem
- Background
- Problem Formulation
- Resource-aware Multi-gateway WMN Video Multicasting
- Performance Evaluation
- Conclusions

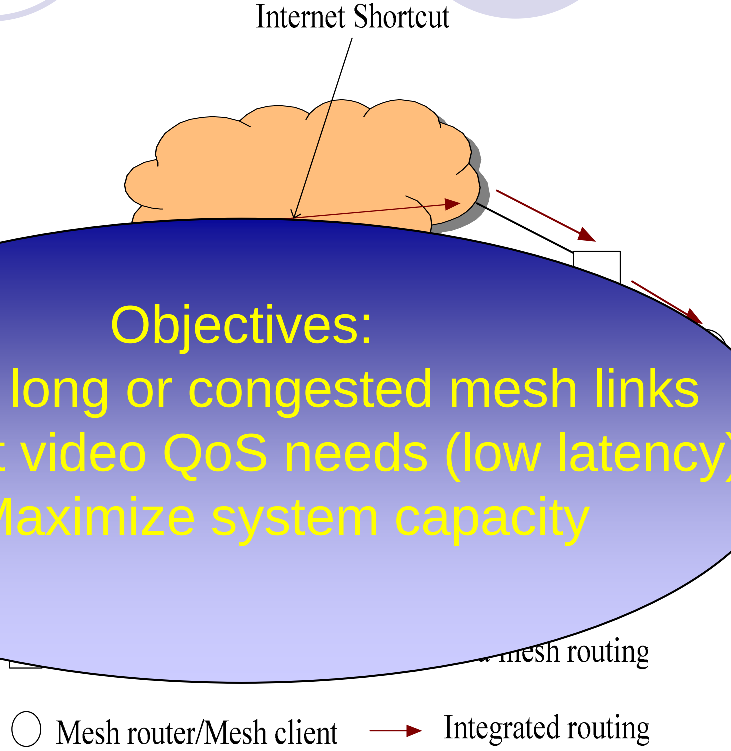
The Problem: Video Multicasting in a Mesh

S → R:

Intra-mesh rou... least 6 wirel...

Integrated r... wireless hops

Integrated routing is better



Objectives:

i) Avoid long or congested mesh links
ii) Support video QoS needs (low latency)
iii) Maximize system capacity

S → N:

Intra-mesh routing: 2 wireless hops

Integrated routing: 2 wireless hops

Intra-mesh routing is better

- Motivation – develop a video multicasting framework, for extended WMN environment, that seeks to efficiently exploit available Internet resources while cooperatively sharing the intra-WMN wireless bandwidth

Problem Formulation..1

- Wireless communication cost causing the great degradation of wireless video signals

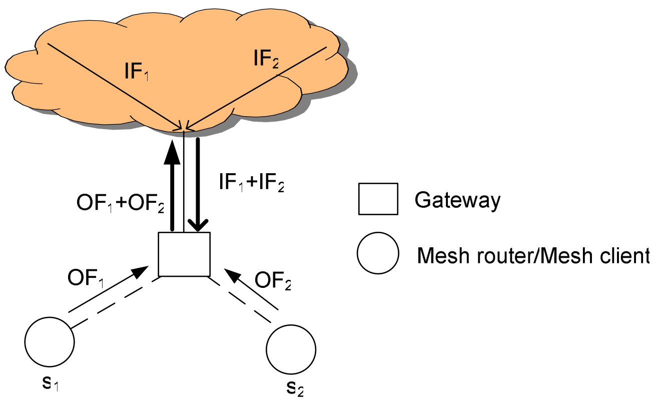
Use r_V to denote the video stream *V*'s transmission rate, C_l to denote the *l*th link's throughput, I_l to denote the *l*th link's capacity loss caused by interference and contention, L to denote the number of wireless links used by *V*, *P* to denote the total number of packets transmitted by *V*.

- Throughput cost $\delta_T = \sum_{l=0}^{L-1} [\{r_V - C_l\}^+ + I_l]$

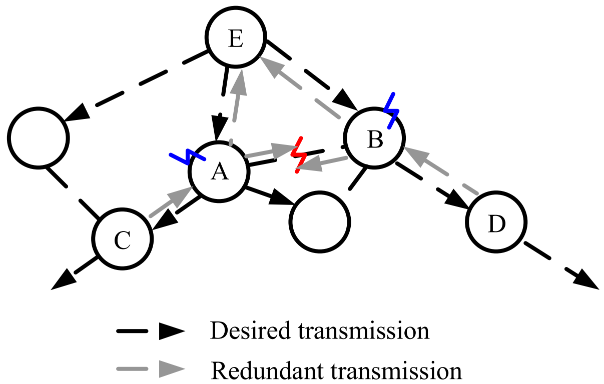
- Smaller path-length → less interference-based capacity loss
  - Need to select 'less congested' paths
  - Goal 1: Use Internet shortcuts to reduce the total number of wireless hops traversed by the video traffic

Problem Formulation…2

- Delay cost $$\delta_D = \frac{\delta_T}{r_V}$$
- Delay jitter cost $$\delta_J = \sum_{p=1}^{P-1} |(\delta_D)_p - (\delta_D)_{p-1}|$$
- With traffic accessing Internet, gateways become hotspots
- A large C_l would reduce the costs of throughput, delay, and delay jitter
- Goal 2: Avoid "busy" gateways



- Goal 3: Decrease I_l caused by interference and contention



Resource-aware Multi-gateway WMN Video Multicasting

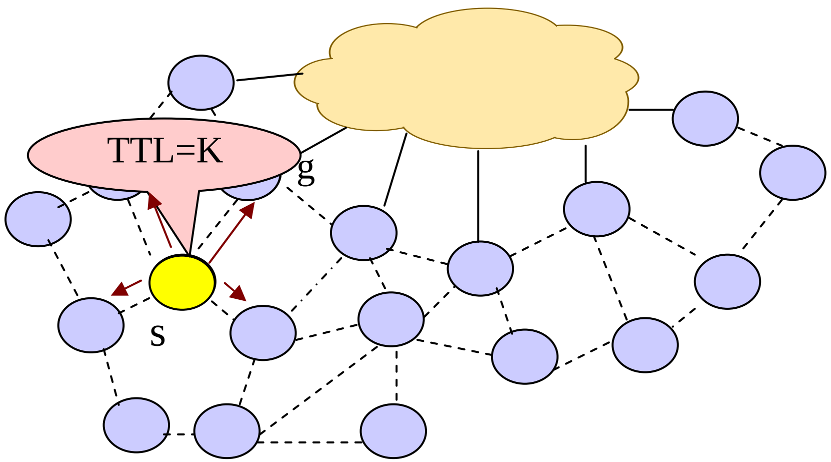
- The proposed mechanism is a 4-step process:
  - Access area construction (k-hop neighborhoods)
    - Two-tier Integrated Architecture (TIA)
  - Identification of less-loaded IGWs (shortcuts)
    - Weighted Gateway Uploading
  - Minimum Forwarding Overhead Routing
    - Link-Controlled Routing Tree (LCRT)
  - Channel assignment to avoid interference
    - Alternative Channel Assignment (ACA)

Access Area Construction…1

- Two-tier integrated architecture
  - *K-hop access area* construction (Source-based clustering).

    - Cluster the WMN group into several *access areas* that include the group members within *K* hops to the initiators

    -Source *s* broadcasts AREA_CONSTRUCTION with TTL=K to create a K-hop neighborhood *(access area*)



K is determined by the choice of radio interfaces/channels, the propagation environment, the video data rate, and the QoS desired by the application

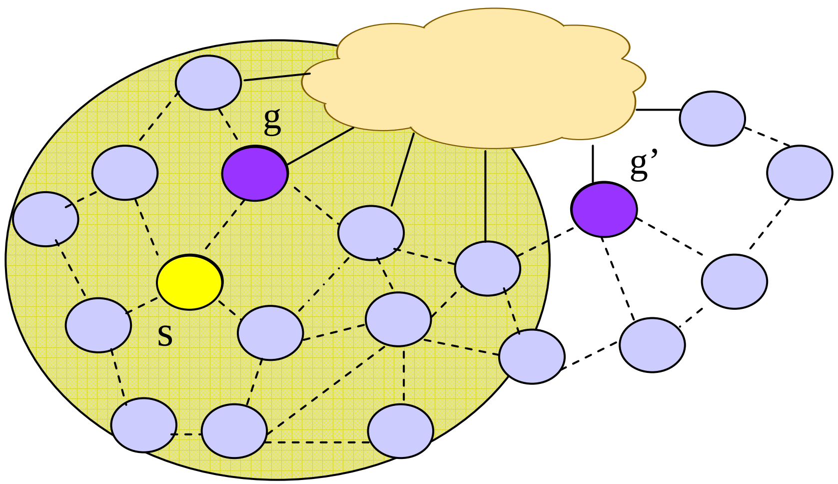
Access Area Construction…2

- Two-tier integrated architecture
  - *K-hop access area* construction using Internet shortcuts.

    -Cluster the WMN group into several *access areas* that include the group members within *K* hops to the initiators

    -The initiator of the first *access area* is the sending source *s* who broadcasts AREA_CONSTRUCTION

    - *s* selects an *uploading gateway* (*g)* who sends SEARCH to find an *area gateway* (*g')* as the initiator of a new *access area*



Apart from *K*=*K*-*k*, where *k* is the number of hops from *s* to *g*, the same operations as *s* does are employed by the *area gateway g'* to construct a new *access area*

Access Area Construction…3 (finer details)

- Dynamic Access Area

When a member cannot achieve an acceptable QoS level for the video
- The member sends QUALITY_REPORT to the report destination
- If the member is in the source *access area,* the sending source is the report destination. The sending source updates the source *access area* into a (*h*-*1*)-hop area; each area gateway changes its *access area* into a (*h*-*1*-*k*)-hop area.
- If the member is in the non-source *access area*, the *area gateway* is the report destination. Only the *access area* including the member needs to change its size to a (*h*-*1*-*k*) area.

When the network conditions improve after shrinking
- Shrinking the range of *access area* may leave some group members uncovered by any *access area*
-*Pending* members will be admitted back into their *access areas*

Weighted Gateway Uploading

Weighted Gateway Uploading

- Select an *uploading gateway* through which the sender can implement a real-time and high-throughput uploading
- Assign each reachable gateway a weight and selects the gateway with the largest weight as the *uploading gateway*
- The weight of each reachable gateway is calculated by

$$w_i = \frac{C_i}{h_i}, i \in [0, G'-1],$$

where C_i is the current available capacity of the ith gateway, and h_i is the distance of the ith gateway to s.

- The selection of *uploading gateway* uses a load-distance balanced metric to find a “non-busy” and close gateway, and therefore avoid bottleneck gateway nodes

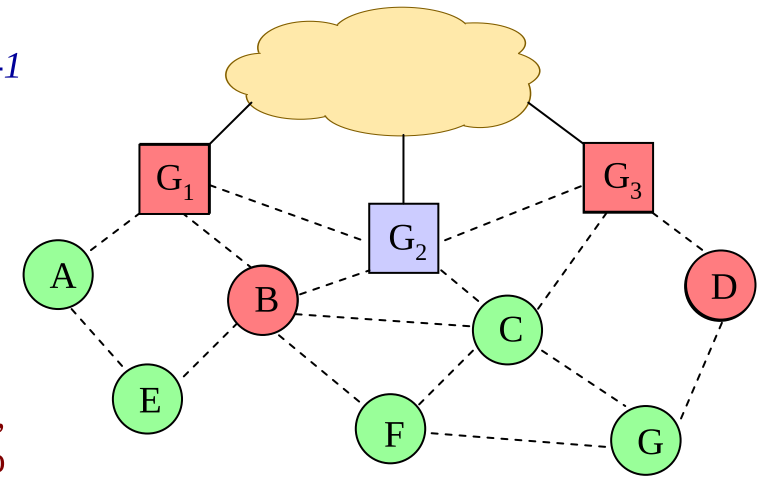
Intra-Access Area Routing

Link-controlled Routing Tree

- Variant of Minimum Vertex Cover Algorithm (Multicast version)– Find the least number of forwarding nodes that cover all multicast receivers
- Run by the sender in the source *access area*/the *area gateway* in the non-source *access area*
  - *Node level* - the least number of wireless hops from the node to its closest gateway
  - *Uncovered out degree* - the node's number of direct child members who have not found their Forwarders

- Begin from the nodes whose *node levels* are *L-1*
- Select a (*L-1*)-level node who covers the most number of uncovered L-level nodes and has the least connection with (*L-1*)-level nodes
- Select on-tree forwarders from the (*L-2*)-level nodes by the same way

L is the largest *node level* in the *access area*, i.e., the worst number of hops among all members to the *area gateway*



Channel Assignment and Interference Mitigation

◈ Alternative Channel Assignment

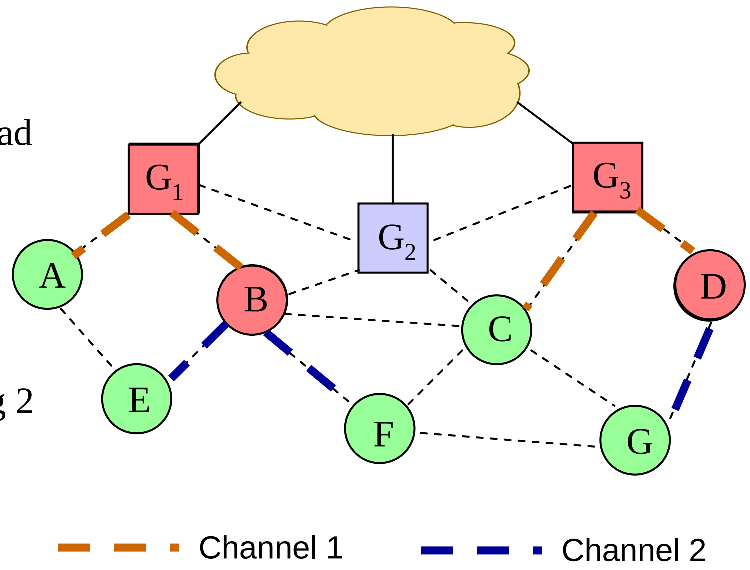
- Each mesh node has two different radio interfaces (sending and receiving) that are assigned to each group member
- Beginning at the sender of the source *access area*/the *area gateway* of each non-source *access area*, the roles of radio interfaces at successive nodes are set alternatively
- Greatly decrease interference caused by the video transmission at successive nodes

Why 2 different channels?

-Simple assignment control and low control overhead

- Works well when group members of different sources are not overlapping

- When group members of different sources are densely overlapping, more than 2 interfaces are required to assign to different sources or scheduling 2 interfaces



Performance Evaluation

- Four protocols are simulated

  -EM: Using Internet shortcuts greedily
  -IR: Intra-mesh routing using wireless media broadcasting to deliver packets
  -RMG: Our protocol
  -IW: A reduced version of our protocol, only including *two-tier architecture* and *weighted gateway uploading* (no channel diversity)

- Performance metrics

  -Average multicast delay (AMD)

$$AMD = \frac{\sum_{i=0}^{n-1} AD_i}{n}$$

AD_i → the average packet delay at the *i*th member

n → the group size

  -Average multicast throughput (AMT)

$$AMT = \frac{\sum_{i=0}^{n-1} AT_i}{n}$$

AT_i → the average packet throughput at the *i*th member

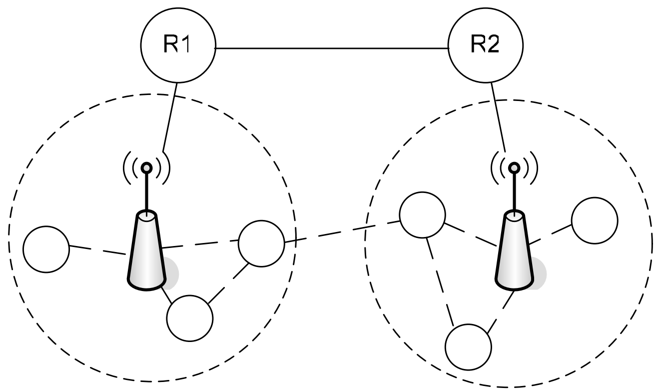
  -Average multicast delay jitter (AMDJ)

$$AMDJ = \frac{\sum_{i=0}^{n-1} ADJ_i}{n}$$

ADJ_i → the average video delay jitter at the *i*th member

Performance Evaluation

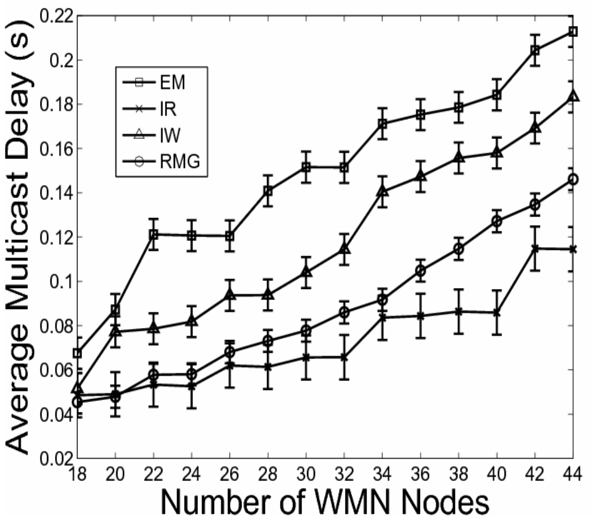
- Evaluation using a small-scale WMN

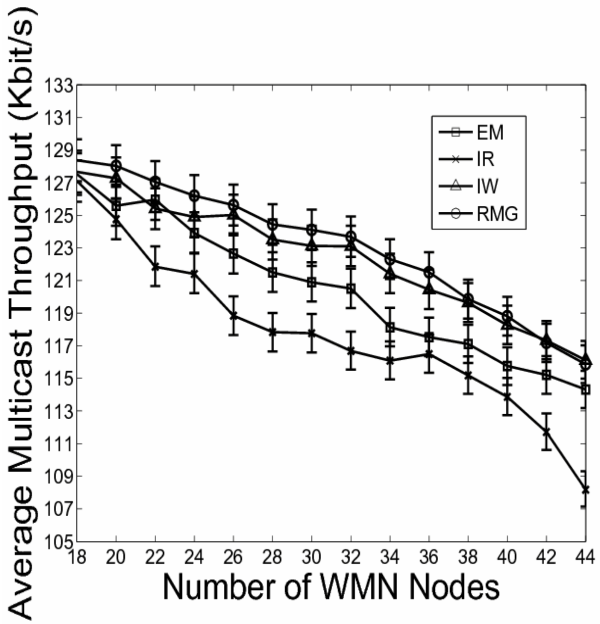


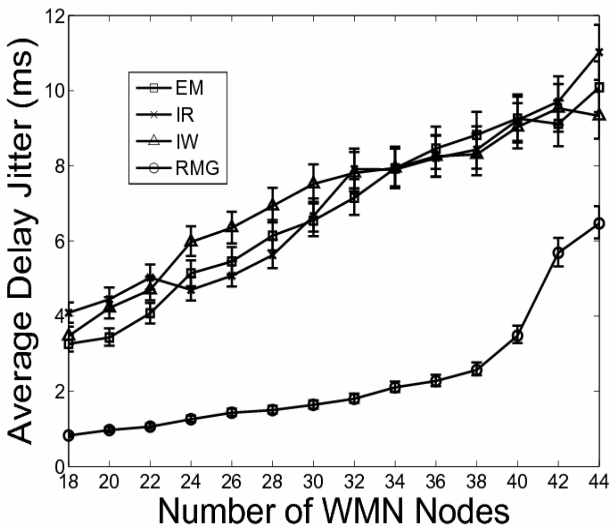
- Two wired routers (R1 and R2)
- Bandwidth of the wired link connecting them is 1000Mbit/s
- Bandwidth of the wired link connecting WMN gateways to routers is 1000Mbit/s
- In RMG, each WMN node has 2 single-channel radio interfaces; in other protocols, only 1 radio interfaces
- Group size varies from 18 to 44
- Results are the average of 10 runs

Performance Evaluation

- 10-20% increase in multicast throughput
- Much more dramatic reduction in delay (75%) and jitter (~75%, down to 2 msec) compared to pure intra-mesh routing.

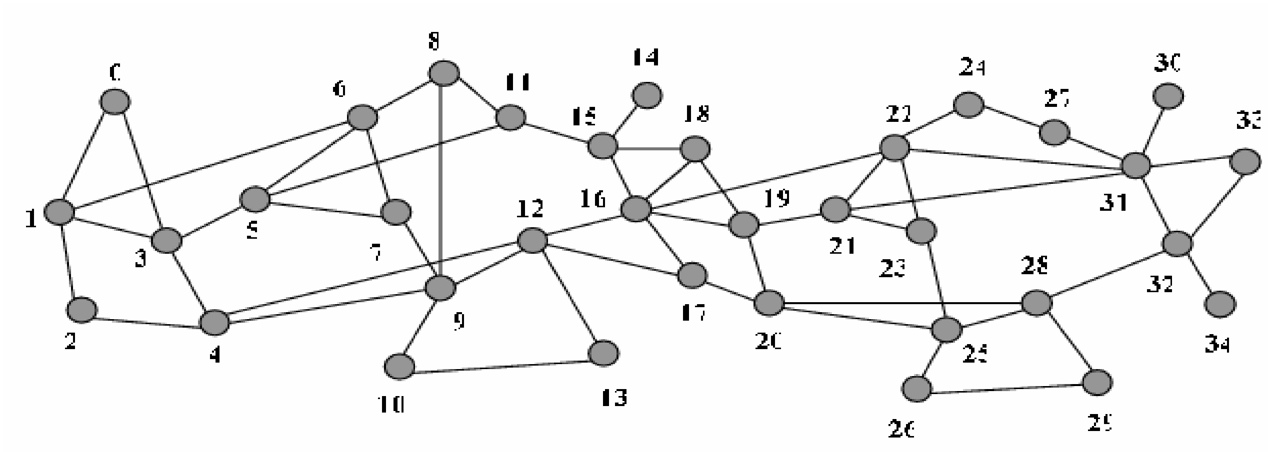






Performance Evaluation

- Evaluation using a large-scale WMN



• The topology is the wired backbone of the simulation (obtained from MCI backbone networks).

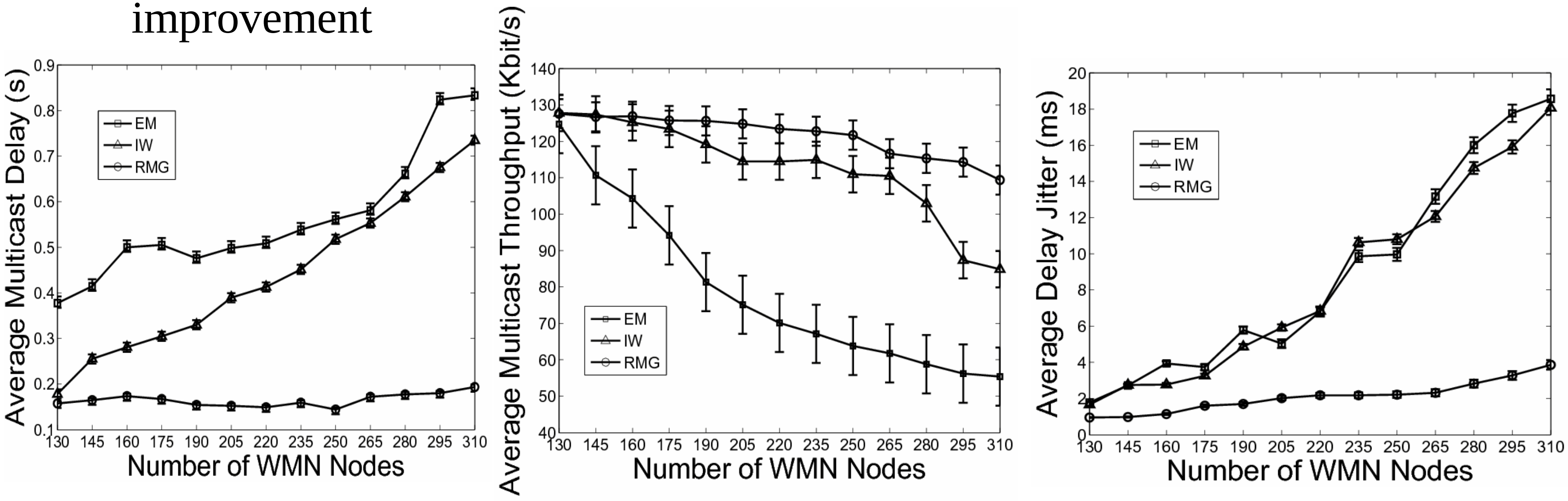
• Each router represents a domain and connects to other routers through 1000Mbit/s

• Bandwidth of the wired link connecting WMN gateways to routers is 1000Mbit/s

• 2 single-channel radio interfaces in RMG; 1 radio interface in other protocols

Performance Evaluation

- Throughput improves by almost 100% and jitter is bounded to ~4msec by RMG
- Channel diversity (reduced interference) gives 20-30% improvement



Conclusion

- We propose an integrated architecture for video multicasting in mesh networks.
  - Combine good intra-mesh routing with appropriate use of Internet (wired) shortcuts.
- 4-step protocol involves:
  - *two-tier integrated architecture*, using IGWs to limit intra-mesh forwarding to k-hops.
  - *weighted gateway uploading* algorithm to balance between 'nearby' and busy gateways'
  - *link-controlled routing tree* algorithm to perform intra-access area forwarding with smallest number of 'independent' forwarders
  - *alternative channel assignment* algorithm minimizes interference
- Observable increase in throughput, but dramatic improvements in delay and jitter (~75%).

Thank you!

Questions?

Related Work

- Intra-mesh schemes
  - Rate and contention aware multicast – B. Liu *et al.*
  - Multiple rate optimization – C. Chou *et al.*
  - Fast broadcast tree – Wang *et al.*
  - Per-node throughput analysis of a random multi-hop network – S. Shakkottai *et al.*

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- Integrated routing
  - Prefix continuity-based greedy integrated routing – P. Ruiz *et al.*
  - Hybrid routing protocol – Y. Amir *et al.*

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Performance Evaluation

- Impact of Multiple Gateways.
  - The impact of the number of gateways and the number of nodes in the source *access area* on the average throughput performance of RMG
  - The number of gateways per source *access area* varies from 1 to 5, and the number of nodes in the source *access area* varies from 5 to 45
  - The total number of members in other *access areas* is 240