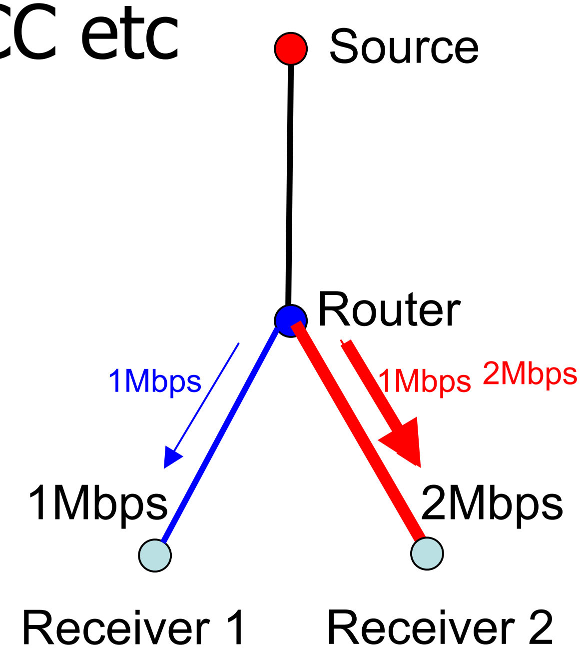
Generalized Multicast Congestion Control (GMCC)

Jiang Li, Shiv Kalyanaraman
Rensselaer Polytechnic Institute
Troy, NY, USA
Jiang is now with Howard University
Email: shivkuma@ecse.rpi.edu
Google: "**Shiv Kalyanaraman**"

Multicast Congestion Control: History

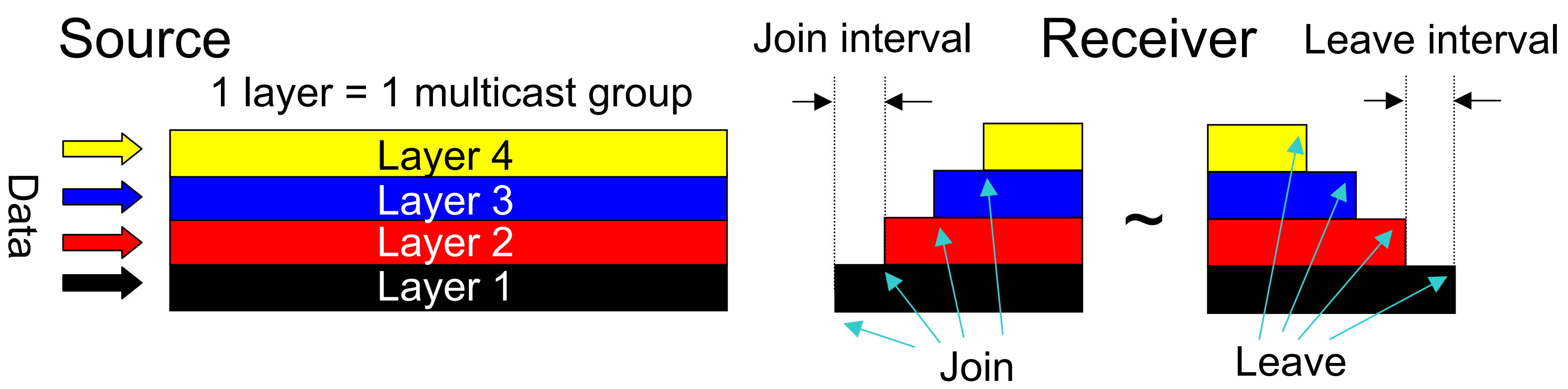
- **Single-rate**
  - PGMCC,TFMCC,ORMCC etc
- **Multi-rate**
  - RLM,RLC,FLID-DL...



Can we construct multi-rate schemes using single-rate schemes as building blocks?

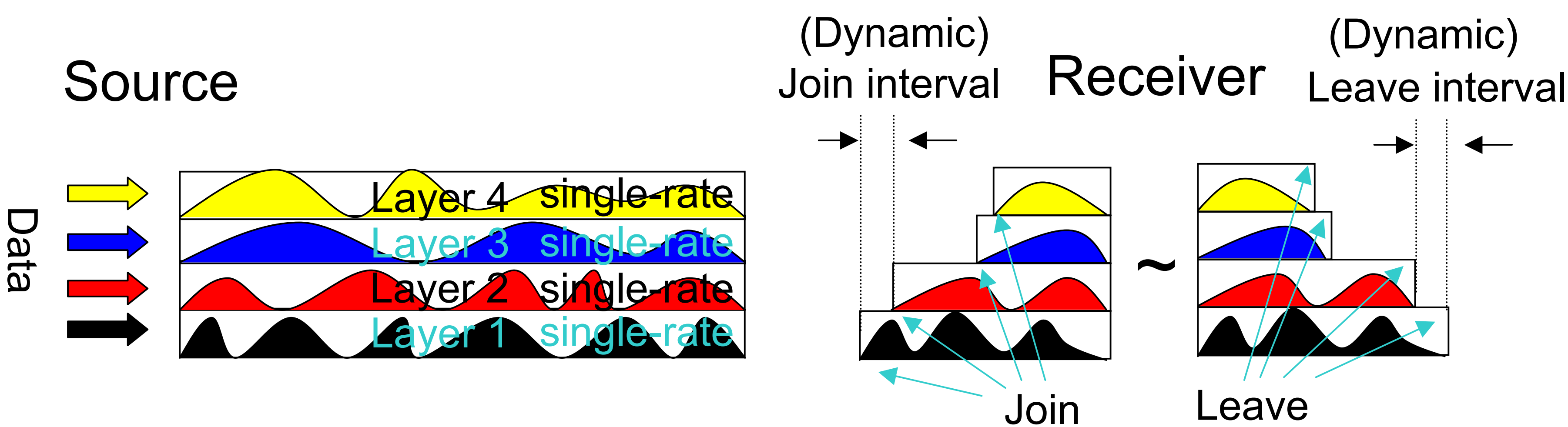
Prior Work: Receiver-Driven Multi-Rate Schemes

- The source sends data in each layer at same rate per layer (or using a fixed schedule)
- Receivers increase/decrease by joining/leaving layers
  - Coarse control, heavy router burden



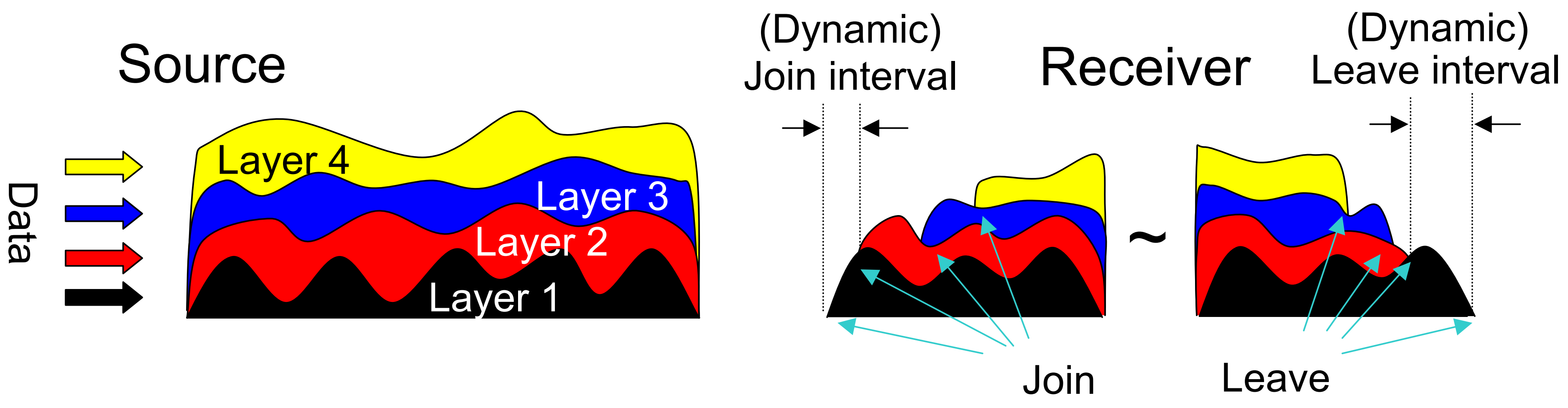
Prior Multi-Rate Schemes: SMCC

- Source uses a single-rate MCC scheme
- Static layering (pre-defined maximum rate per layer)
  - More layers than necessary, especially when heterogeneity is large

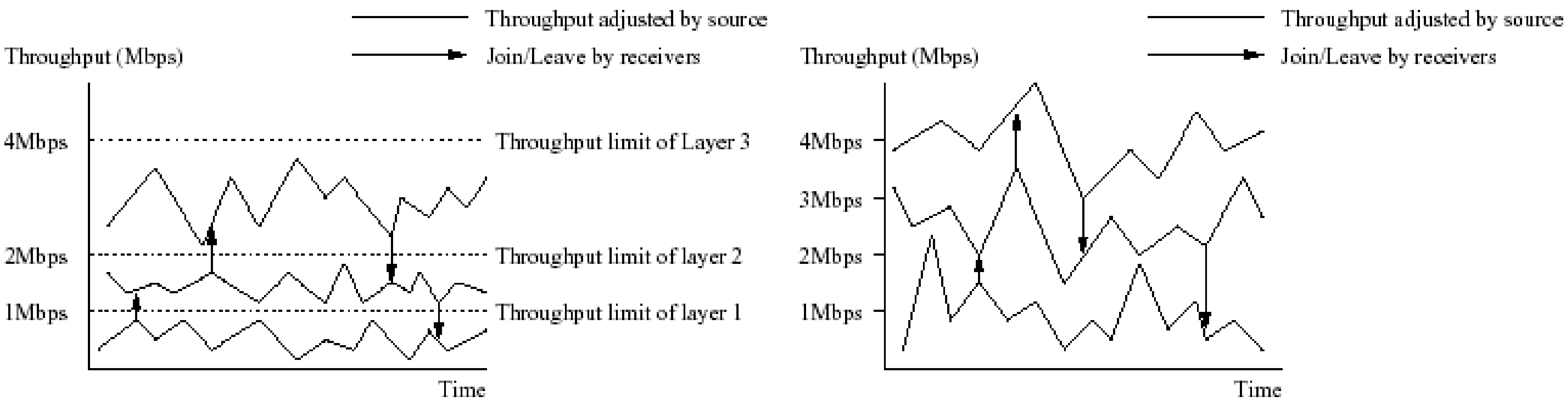


GMCC:Tiramasu Ice-Cream Cake Model

- Single-rate congestion control in each layer
- Dynamic layering (no rate limit for each layer)
  - Fully adaptive
  - Fewer layers,
  - Fewer join/leaves,
  - Full source-control of rates



SMCC vs GMCC



(a) SMCC overview
(with per-layer throughput limit)

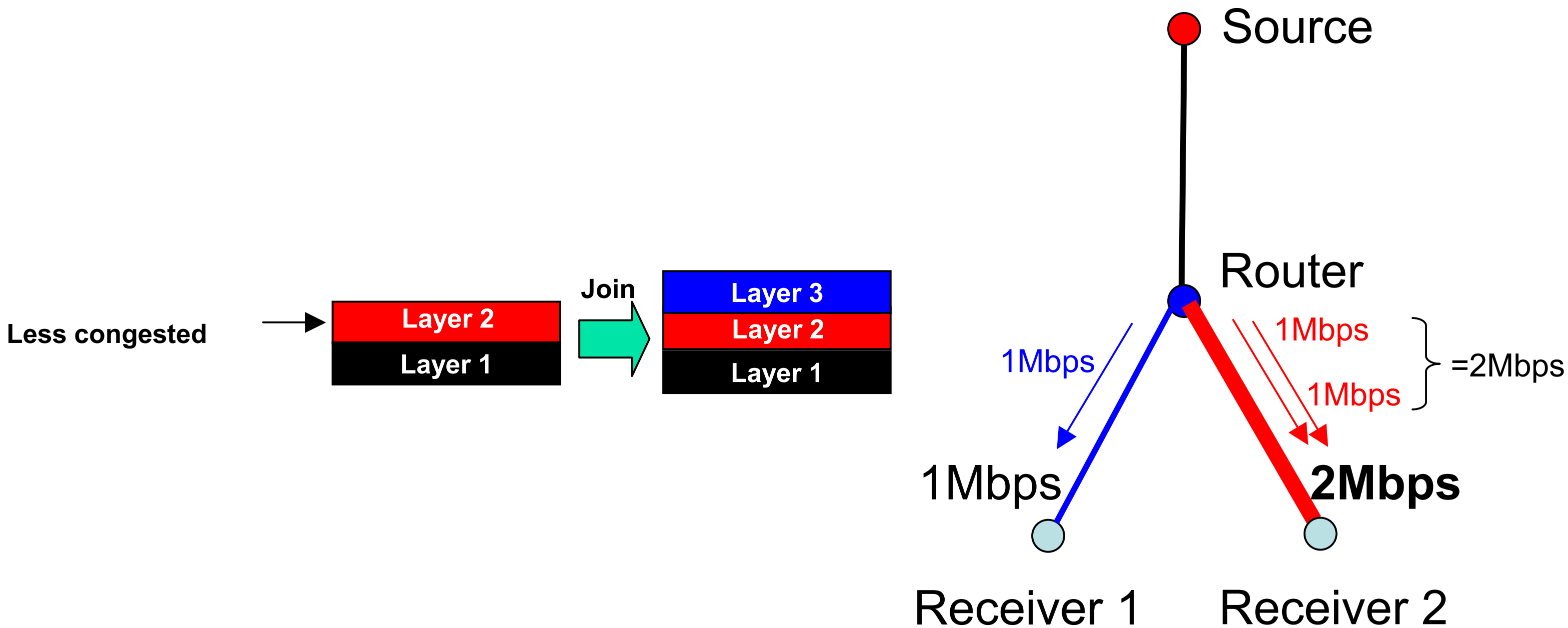
(b) GMCC overview
(no per-layer throughput limit)

GMCC Design

- Use a highly sensitive congestion measure
  - Congestion representative for each layer (single-rate CC)
  - Built on top of an earlier single rate scheme (ORMCC), but PGMCC or TFMCC can be used instead
- **Join** new layer if:
  - Receiver detects that it is not the congestion representative for its highest layer, and
  - Its throughput during congestion epochs is *sufficiently* higher than the representative in the highest layer (allowing for statistical fluctuations, I.e. beyond a confidence interval)
- **Leave** top layer:
  - If the receiver detects that it is the congestion representative in two layers

GMCC: Join

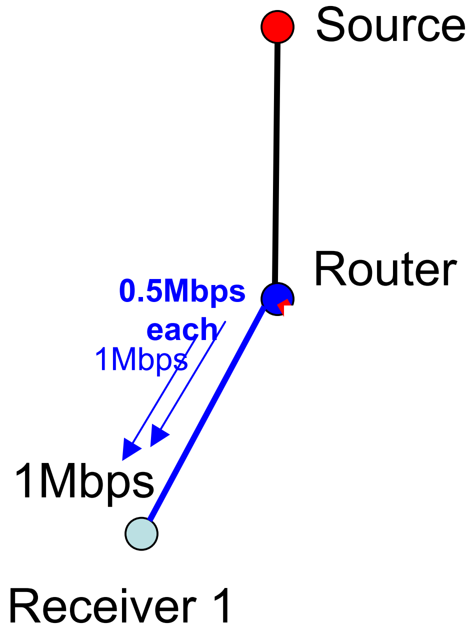
- "Unsatisfied" receivers join a new layer.
  - Much less congested than the representative



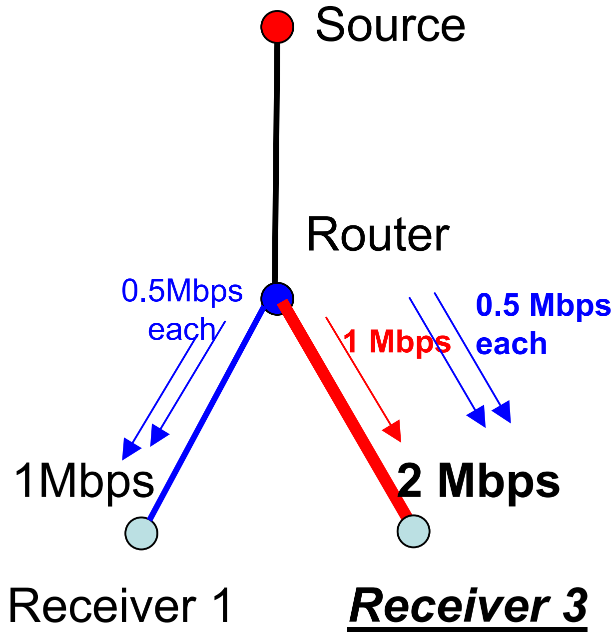
GMCC: Leave

- If the receiver detects that it is the congestion representative in two layers
  - Otherwise other receivers have to join more layers than necessary

GMCC Leave: Motivation



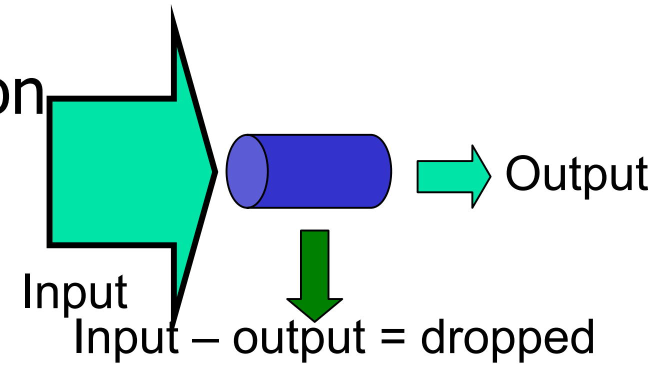
GMCC Leave: Motivation (contd)



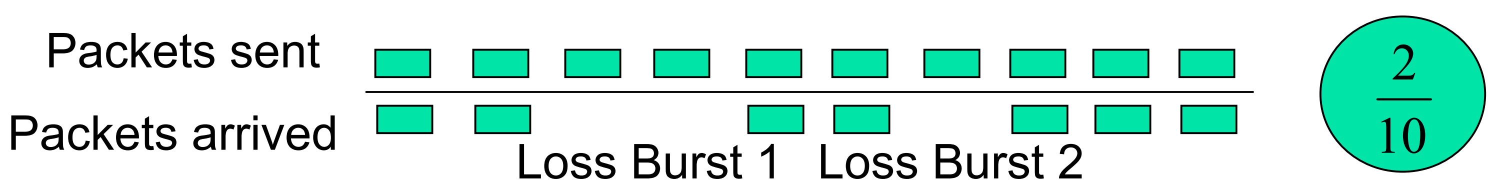
Leads to proliferation of layers in dynamic, heterogeneous scenarios

Conservative Short-Term Congestion Measure: Drives Group Join Decision

- Throughput Attenuation
  - A: Individual throughput attenuation
    - 1 - (output/input)(at congestion)
    - Severity of congestion



  - B: Congestion occurrence rate
    - Number of packet loss bursts / Total sent packets
    - Bursty loss penalized more than random loss



TAF = A • B. Higher TAF, more congested

Representatives

- No layer joins if the congestion measure within confidence interval of representative (in top layer)

$$\left[(\mu_1 - \mu_2) - Z_{\alpha/2}\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}},\quad (\mu_1 - \mu_2) + Z_{\alpha/2}\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}\right]$$

- If congestion measure of node 1 is significantly larger than node 2, node 1 becomes the representative

$$\mu_1 \geq \mu_2 + Z_{\alpha/2}\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}$$

- Modified condition (bias):

$$\mu_1 \geq c\mu_2 + Z_{\alpha/2}\sqrt{\frac{\sigma_1^2}{n_1} + \frac{(c\sigma_2)^2}{n_2}}$$

Join condition…

Receiver **i** joins a new group if its top layer satisfies:
(**j** : representative in top layer)

$$\Theta_j > \beta_1 \Theta_i + \beta_2 \sqrt{\frac{(\beta_1 \Theta_i^{\sigma})^2 + {\Theta_j^{\sigma}}^2}{N}}$$

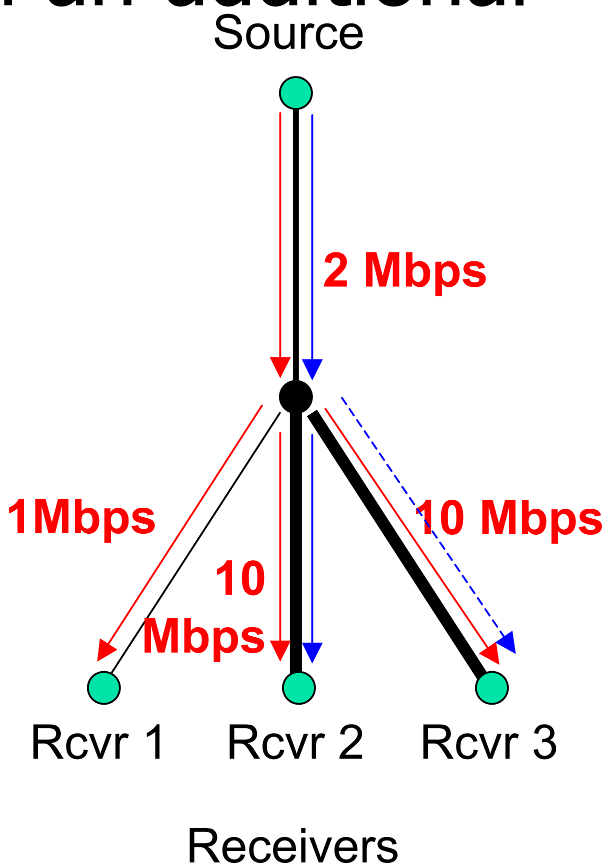
Θ_i	Average TAF of receiver i
Θ_i^{σ}	Standard deviation of receiver i's TAF
N	Number of TAF/ITAF samples kept for calculation

Parameters:

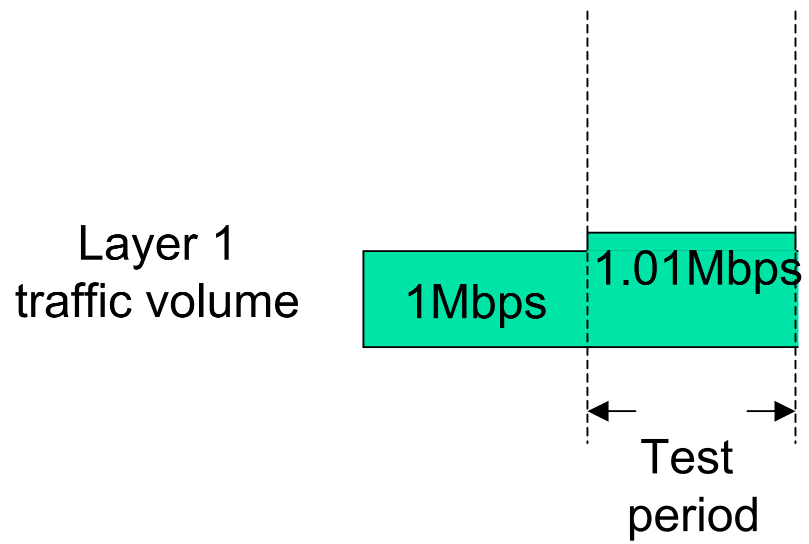
$\beta_1 = 2$, $\beta_2 = 2.58$ for a 99% confidence level.

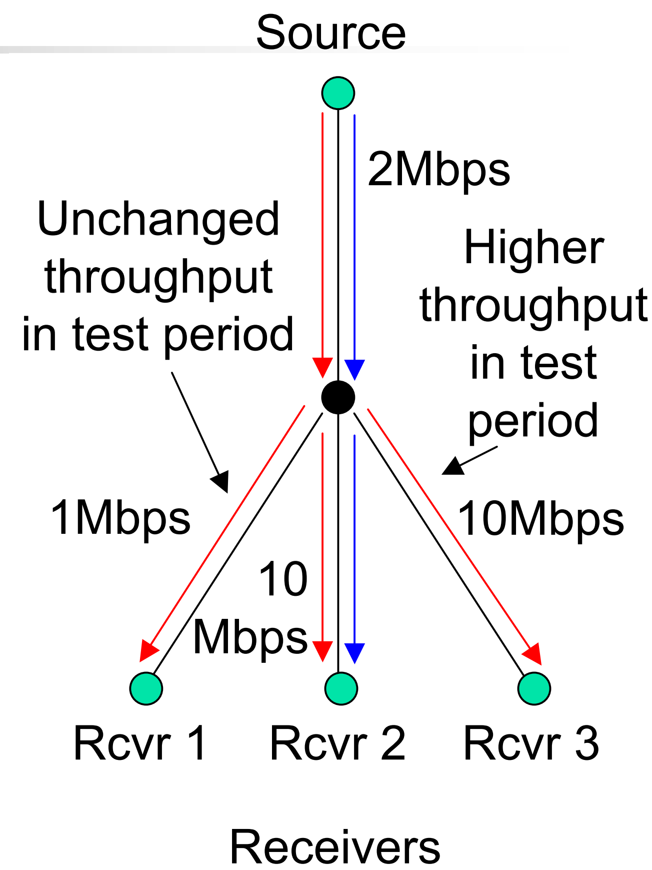
Strengthening the Join Condition

- Receiver 3 may not join an additional group for a while



Strengthening the Join condition (contd)



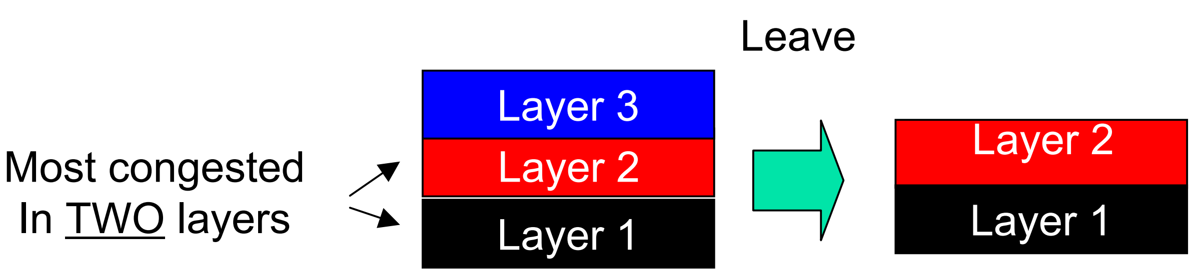


$$\lambda_i + \min(\delta\lambda_i, \lambda_{i+1})$$

Nudge up the transmission rate in layer i briefly so that valid receivers discover that they can join layer i+1

Recall: GMCC Leave Condition

- A receiver leaves its top layer if it is the most congested (I.e. representative) in more than one layer.

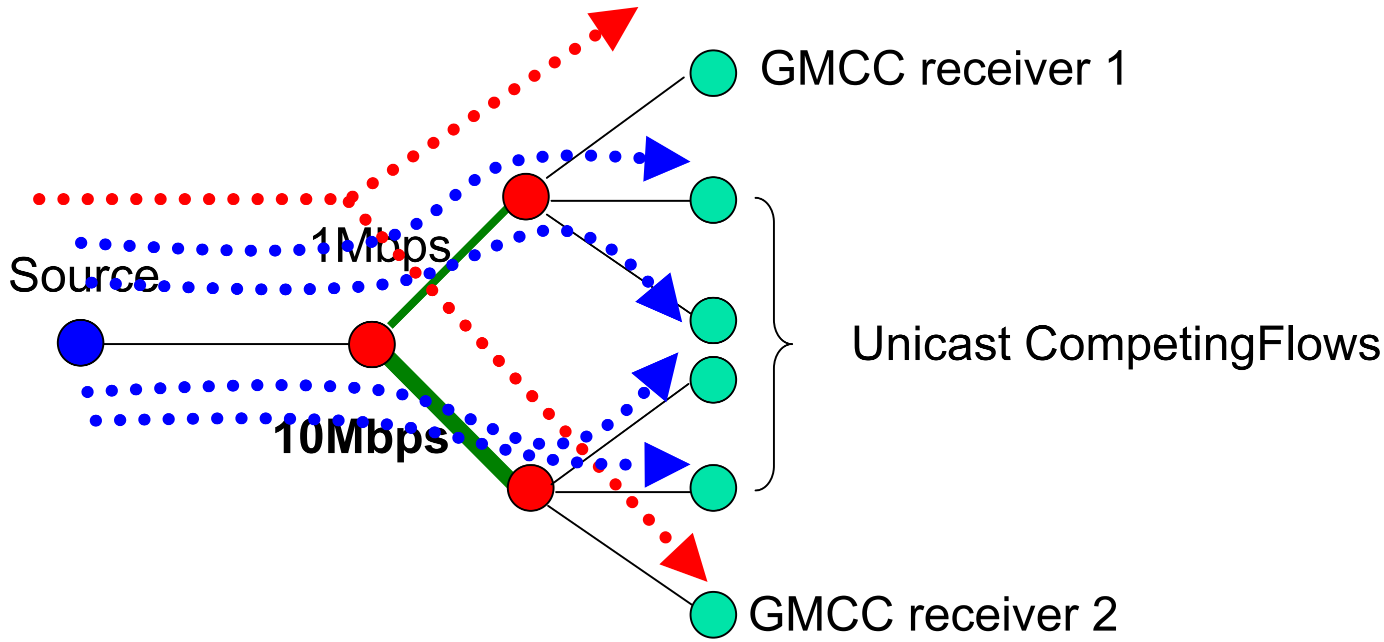


Source Operations

- Regular single-rate multicast congestion control in each layer
  - In accordance with the slowest receiver / layer
  - ORMCC, PGMCC, TFMCC etc.
  - Include the representative's ID and rate in packet headers

- Help receivers discover if they need to join more layers ("nudging")

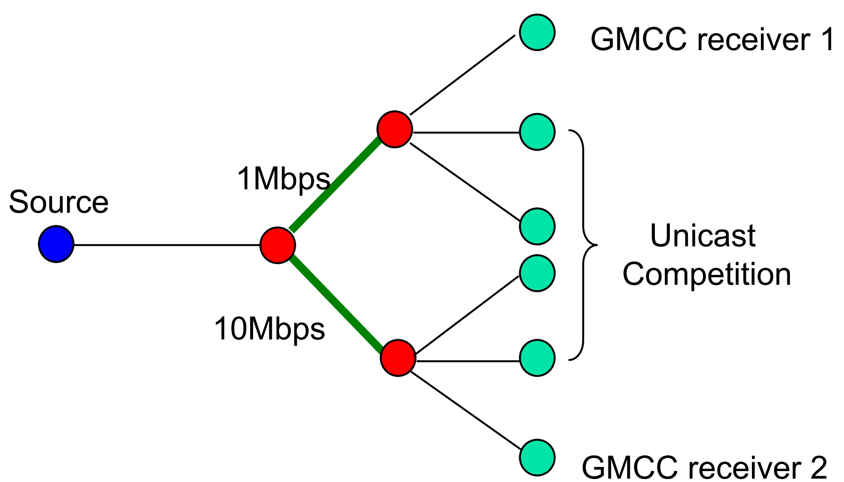
Simulations: Layering Effectiveness

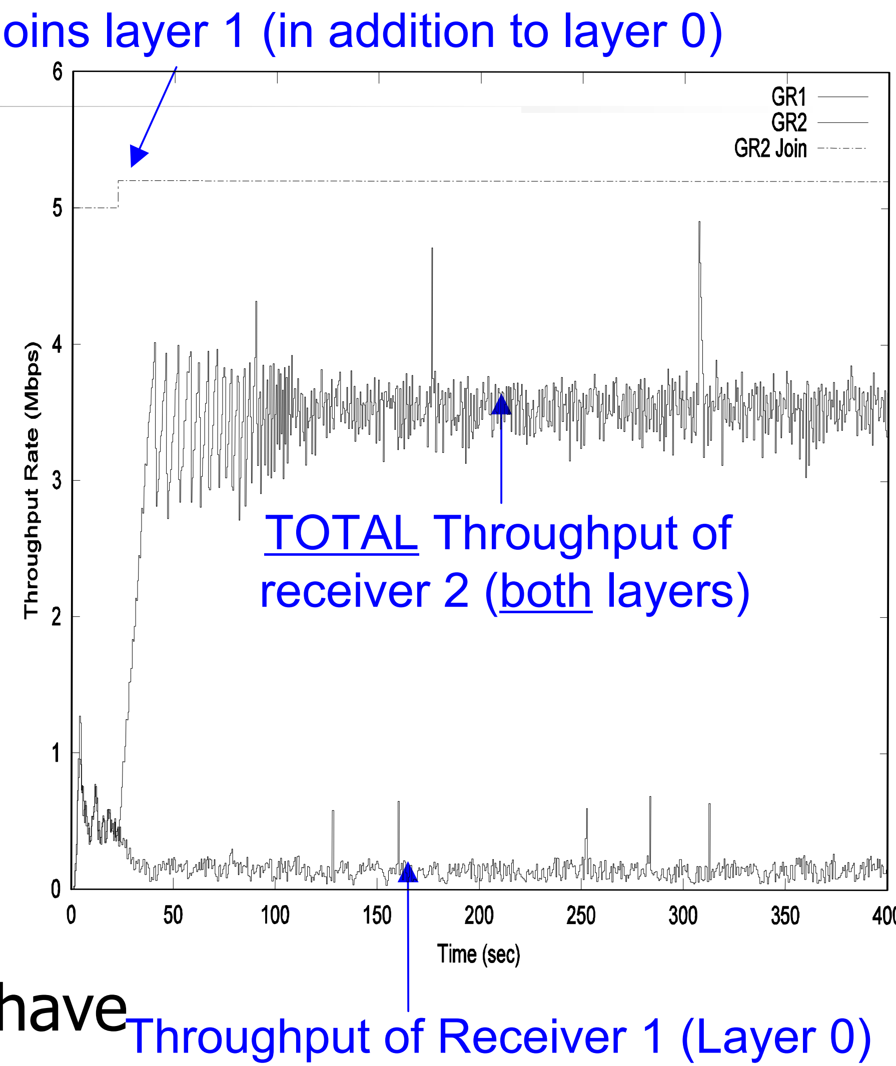


After GMCC Receiver 2 and Unicast Flows join…

Fair rate for GMCC receiver 2 = 3.33 Mbps

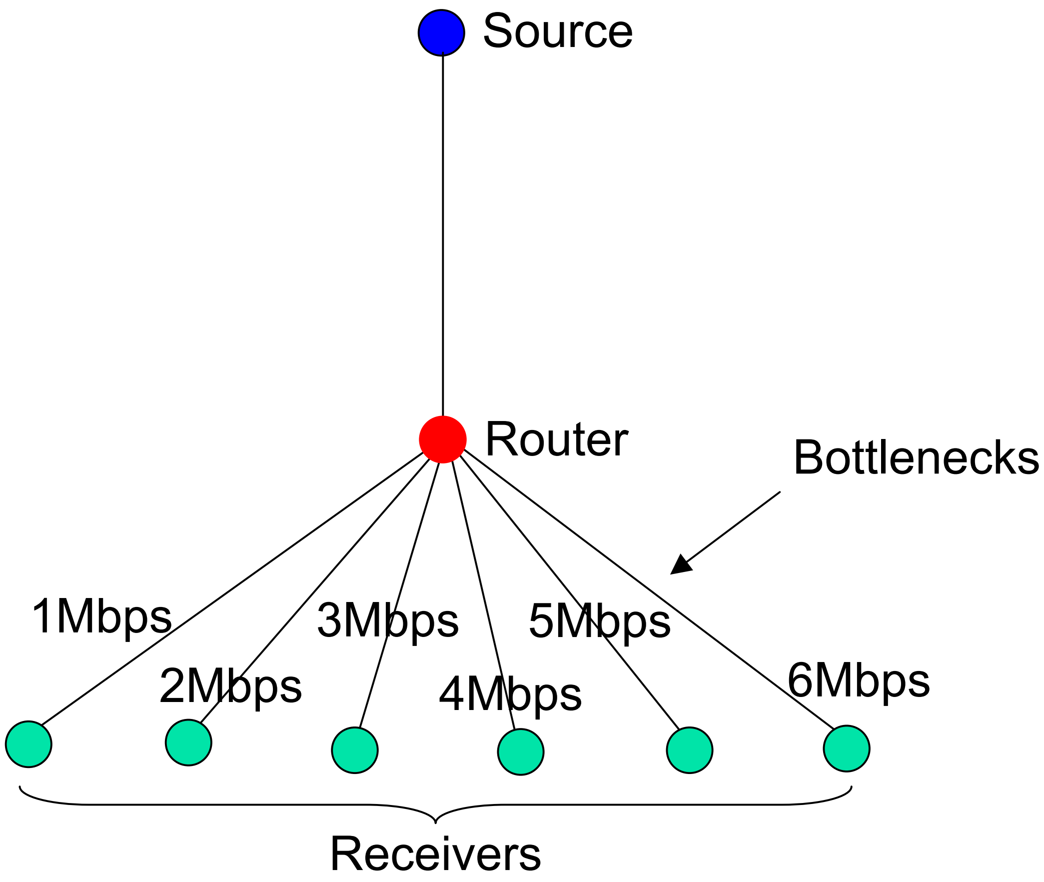
Layering Effectiveness

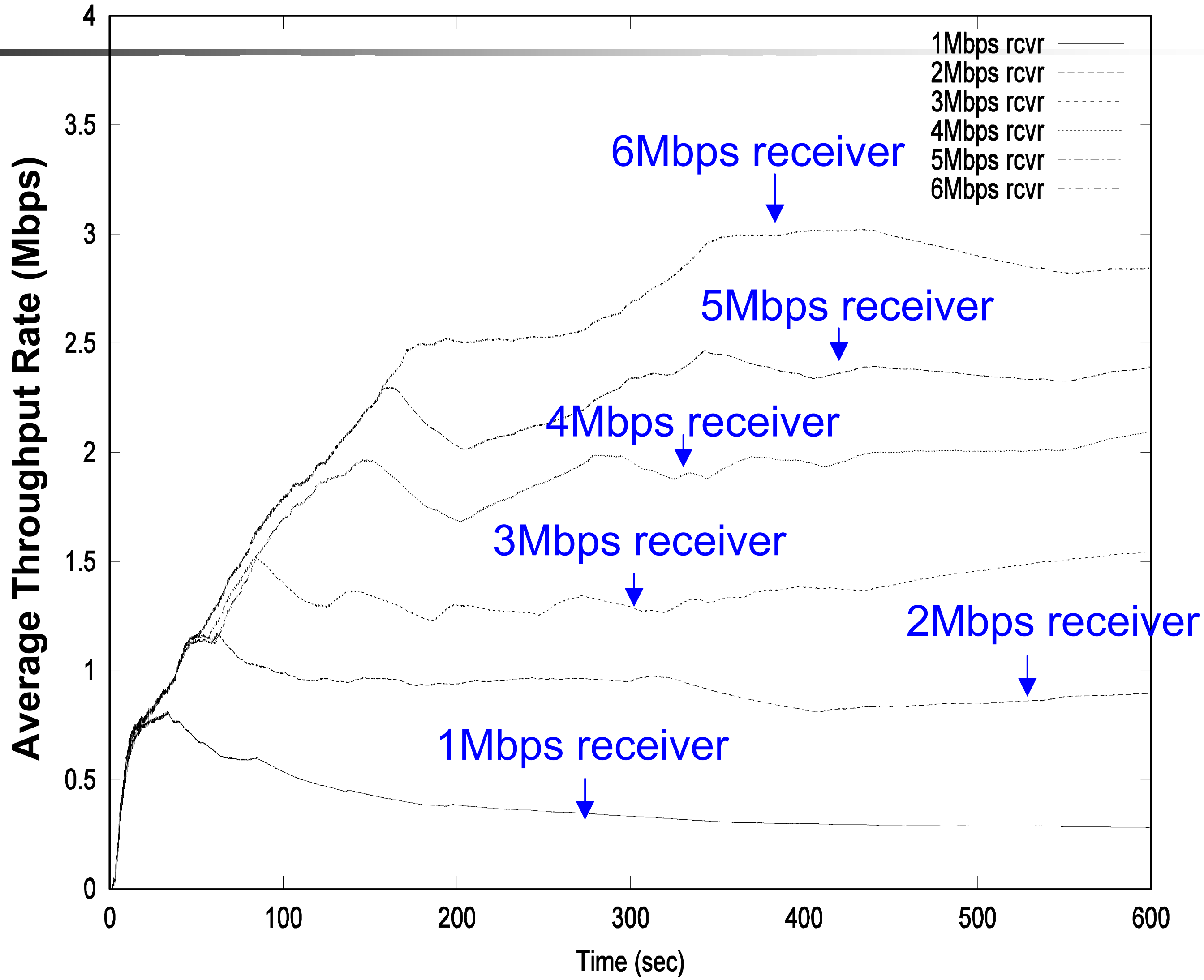




- SMCC would have required more layers;
- Receiver based schemes would have more layers + join-leave load

Throughput Improvement vs Single Rate





Average Throughput Rate (Mbps)
Time (sec)
1Mbps rcvr
2Mbps rcvr
3Mbps rcvr
4Mbps rcvr
5Mbps rcvr
6Mbps rcvr
6Mbps receiver
5Mbps receiver
4Mbps receiver
3Mbps receiver
2Mbps receiver
1Mbps receiver
0
0.5
1
1.5
2
2.5
3
3.5
4
0
100
200
300
400
500
600

Summary

- GMCC is an adaptive layering scheme for synthesizing multi-rate CC from single rate multicast CC schemes
  - Minimizes layering related overhead (seen in receive-based schemes)
  - Instant response to congestion increase (due to source-based control)
  - Few layers, and minimum feedback per layer (eg: PGMCC, ORMCC) => could scale to large groups

- Generic: Can work with PGMCC, TFMCC, ORMCC etc (representative-based schemes)

- **Tradeoff:** uses more conservative measures to guide join/leave decisions

OPEN ISSUES

- Comparison with other multi-rate schemes: validate join/leave cost gains

- Scalability: how does the scheme work with 10-100K receivers, with:
  - high heterogeneity (path rates different)
  - high receiver dynamism
  - background traffic: 100+ TCP background flows in each path

Bottom-line?

- We expect GMCC to scale:
  - more than single-rate schemes
    - Enhance sweet-spot domain of applicability
  - … but not as much as receiver-base multi-rate schemes
    - Eg: very large groups, very high heterogeneity and background traffic/receiver dynamics
- However receiver-based multi-rate schemes have not been validated in these scenarios either!
- *Only now do we have the simulation capability to even ask this question quantitatively…*

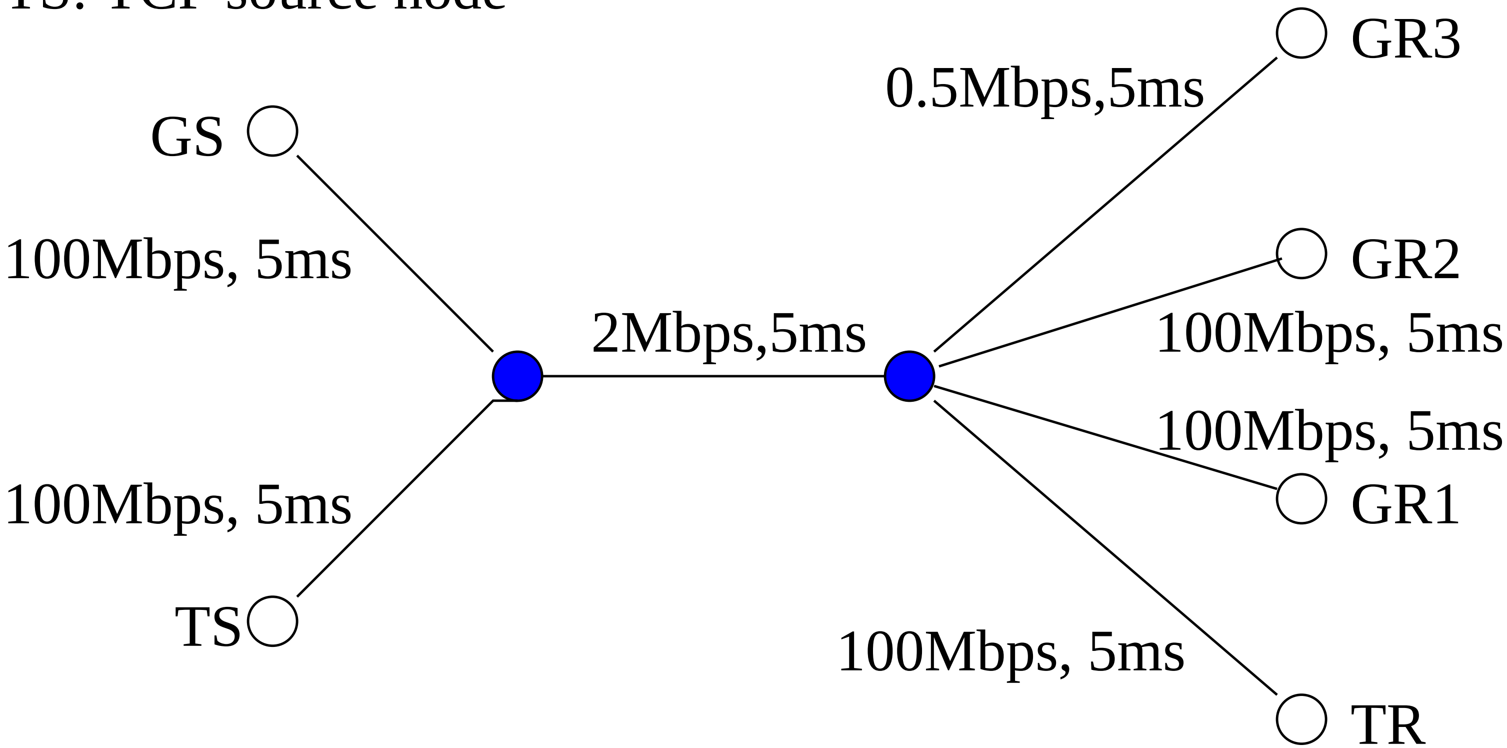
Thank You!

- More information:
  - **Google**: "Shiv Kalyanaraman" or "Shivkumar rpi"
  - **Email:**
    - Jiang: lij6@cs.rpi.edu
    - Shiv: shivkuma@ecse.rpi.edu

EXTRA SLIDES…

Join: probe (PIBS) test

GS: GMCC source node
TS: TCP source node



GMCC Join probe (PIBS) Test