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Multi Class Traffic Analysis of Single and Multi-band Queuing System

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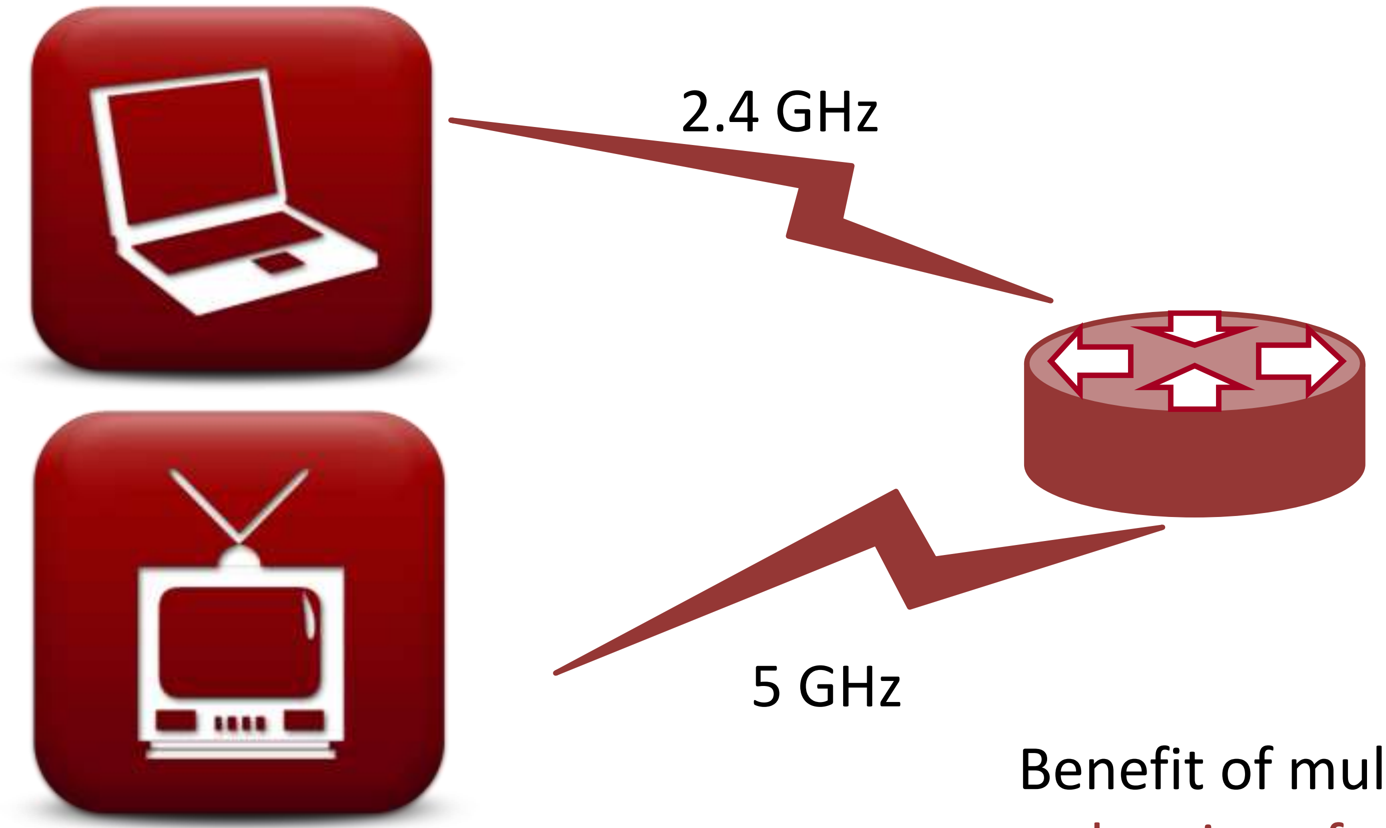
Presentation Outlines

- Single Band Router Architecture
- Proposed Multi Band Router Architecture
- Analytical Models
- Results
- Conclusion

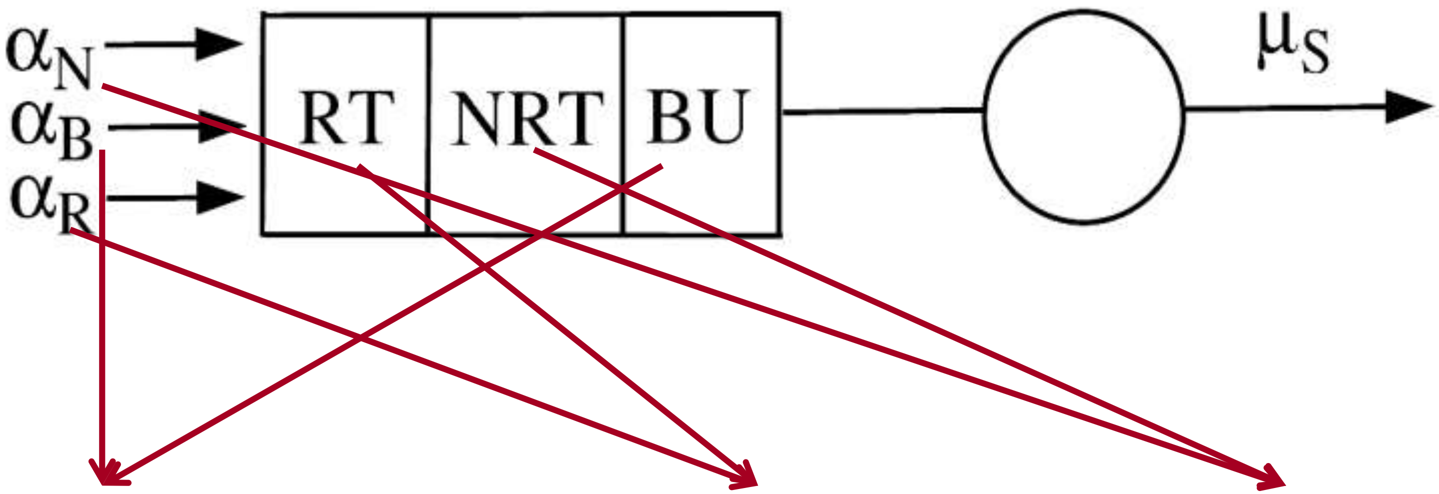
What is Band in Routers?



Benefit of multi-band router

- less interference,
- higher capacity
- better reliability.

Single Band Router Architecture



Binding Update (BU)   Real-time (RT)   NonReal-time (NRT)

- All packet types share one band based on priority.
- Multi-Band approach can allow higher amount of traffic
  - Higher throughput.

Problem Statement

- Current multi-band routers
  - 2.4 and 5 GHz for different types of devices.

- They do not exploit the under utilized frequency band when one is overloaded.

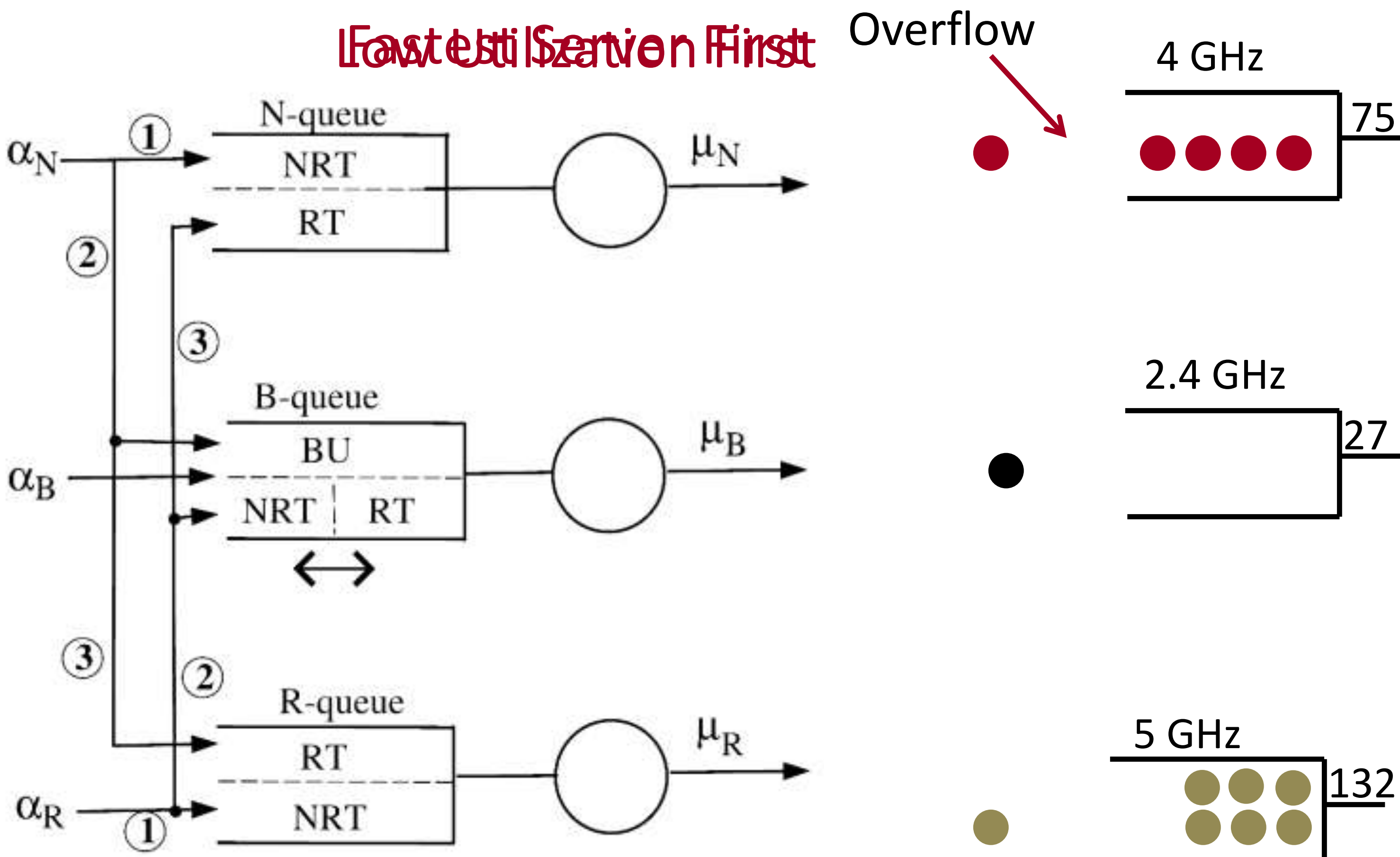
Objectives of this research

- Increase utilization of bands by diverting traffic to under-utilized band. Traffic types:
  - real time,
  - non-real time, and
  - binding update traffic.
- Evaluate performance of multi-band router over single-band architecture.

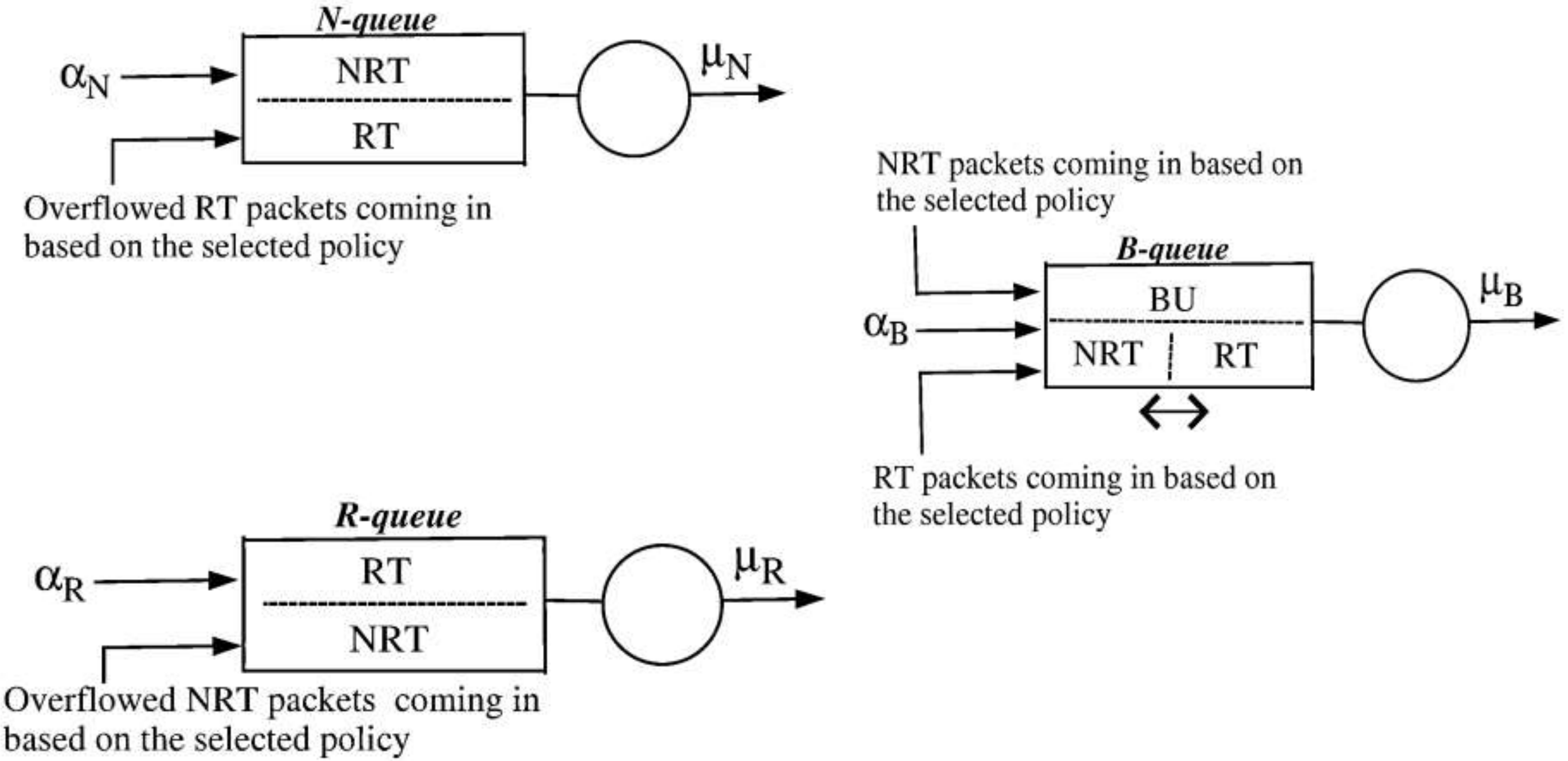
Contribution

- Propose a band-sharing mulitband router architecture
- Scheduling algorithm to ensure maximum utilization of bands.
- Develop analytical model for performance evaluation of proposed multi-band router.
- Compare proposed multiband with single band routers for two scheduling policies.

Proposed Multi Band Router Architecture



Proposed Multi Band Router Architecture



Scheduling Algorithm

- Attempt first made to queue different traffic classes in their corresponding buffers.
- If N-queue overflows, traffic is forwarded to B-queue.
  - Overflowed NRT and RT packets compete in B-queue based on priority.
- If overflowed NRT packets cannot be accommodated in B-queue, they are queued in R-queue.
- Similar policy R-queue overflows.

Analytical Model

- Assumptions:
  - Packet arrival follows Poisson distribution.
  - Type of queue discipline used in the analysis is FIFO with non-preemptive priority among various traffic classes.
- Notations $(T \in \{B, N, R\},)$
  - $N_T \rightarrow \text{Queue size of } T - \text{queue}$
  - $\alpha_T \rightarrow \text{Arrival rate of } T - \text{class}$
  - $\mu_T \rightarrow \text{Service rate of } T - \text{queue}$
  - $E(n) \rightarrow \text{Average occupancy},\ E(D) \rightarrow \text{Average delay}$
  - $P_d \rightarrow \text{Drop rate},\quad \gamma \rightarrow \text{throughput},$
  - $\chi \rightarrow \text{Number of dropped packets}$
  - $E\left(D_{TQ}^{T}\right) \rightarrow \text{Delay of } T - \text{class in } T - \text{queue}$

Analytical Model : Performance Metrics

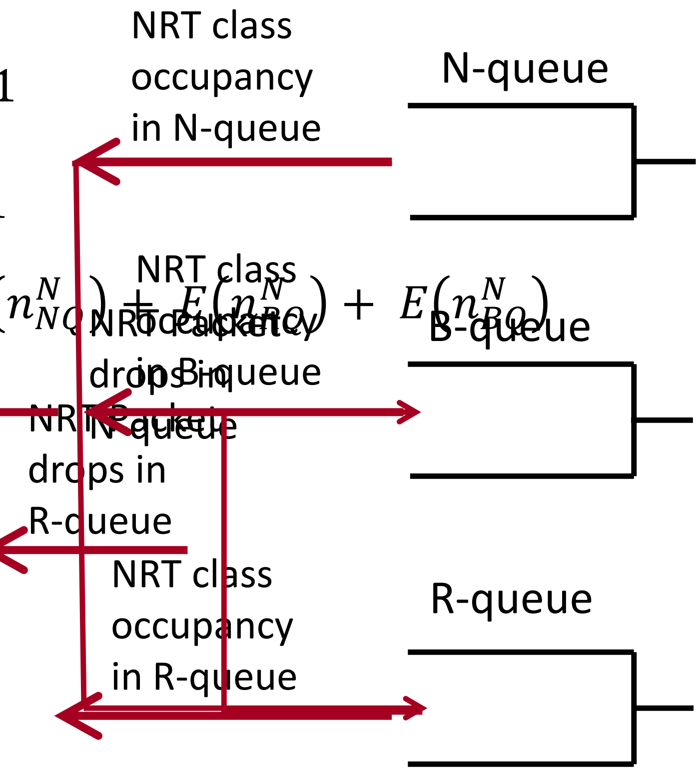
- We have derived approximate ***queue and class based*** **(queue based is each queue such as N-queue performances, class based is each class such as RT traffic)** performance metrics for the proposed multi-band architecture.
  - Packet drop probability
  - Average queue occupancy
  - Throughput
  - Average packet delay
  - Band Utilization

- Possible Cases:
  - Case 0: BU packets are not overflowed at any time (general assumption).
  - Case 1: Only NRT type packets are overflow
  - Case 2: Only RT type packets are overflow
  - Case 3: Both NRT and RT types packets overflow
  - Case 4: NRT and RT types packet do not overflow (M/M/1/N)

Analytical Model: Case 1

- Case 1: Only NRT type packets are overflowed and $\mu_R > \mu_B$ (***FSF***). Let's see NRT performance metrics.

$$E(n_{NQ}^N) = \begin{cases} \frac{\rho_N-(N_N+1)\rho_T^{N_N+1}+N_T\,\rho_N^{N_N+2}}{(1-\rho_N)(1-\rho_N^{N_N+1})} & if \;\; \rho_N \neq 1 \\ \frac{N_N}{2} & if \;\; \rho_N = 1 \end{cases}$$



- Average Occupancy of NRT packets : $E(n_{sys}^N) = E(n_{NQ}^N) + E(n_{RQ}^N) + E(n_{BQ}^N)$
- Drop rate of NRT packets : $P_{dsys}^N = P_{dBQ}^N$
- Throughput : $\gamma_{sys}^N = \alpha_N(1 - P_{dsys}^N)$

$E(n_{BQ}^N) = E(n_B)$ where $E(n_B)$ [13]

$\chi_{NQ}^N = \alpha_N P_{dNQ}^N$

- Average Delay of NRT packets : $E(D_{sys}^N) = \frac{E(n_{sys}^N)}{\gamma_{sys}^N}$

$\chi_{RQ}^N = \alpha_N P_{dNQ}^N P_{dRQ}^N$

$$E(n_{RQ}^N) = E(n_{RQ}) - E(n_R)$$

Analytical Model: MB system

- Averaging ***class base*** metrics to compare multi-band with Single band.
- $E\left(n_{Total}^{MB}\right) = E(n_B) + E(n_N) + E(n_R)$
- $P_{d(avg)}^{MB} = \frac{\alpha_B P_{dB} + \alpha_N P_{dN} + \alpha_R P_{dR}}{(\alpha_B + \alpha_N + \alpha_R)}$
- $\gamma_{all}^{MB} = \gamma_B + \gamma_N + \gamma_R$
- $E\left(D_{avg}^{MB}\right) = \frac{\gamma_B E(D_B) + \gamma_N E(D_N) + \gamma_R E(D_R)}{\gamma_{all}}$

Results

- Discrete event simulation in MATLAB
- MB router buffer size = 50 packets per buffer
- Single band buffer = 150 packets.
- RT and NRT packets: 512 bytes, BU packets: 64 bytes.
- Single band service rate = highest service rate of MB.
- Simulation carried out for 20 trials having different traffic class arrival rates.

Traffic Arrival Rates

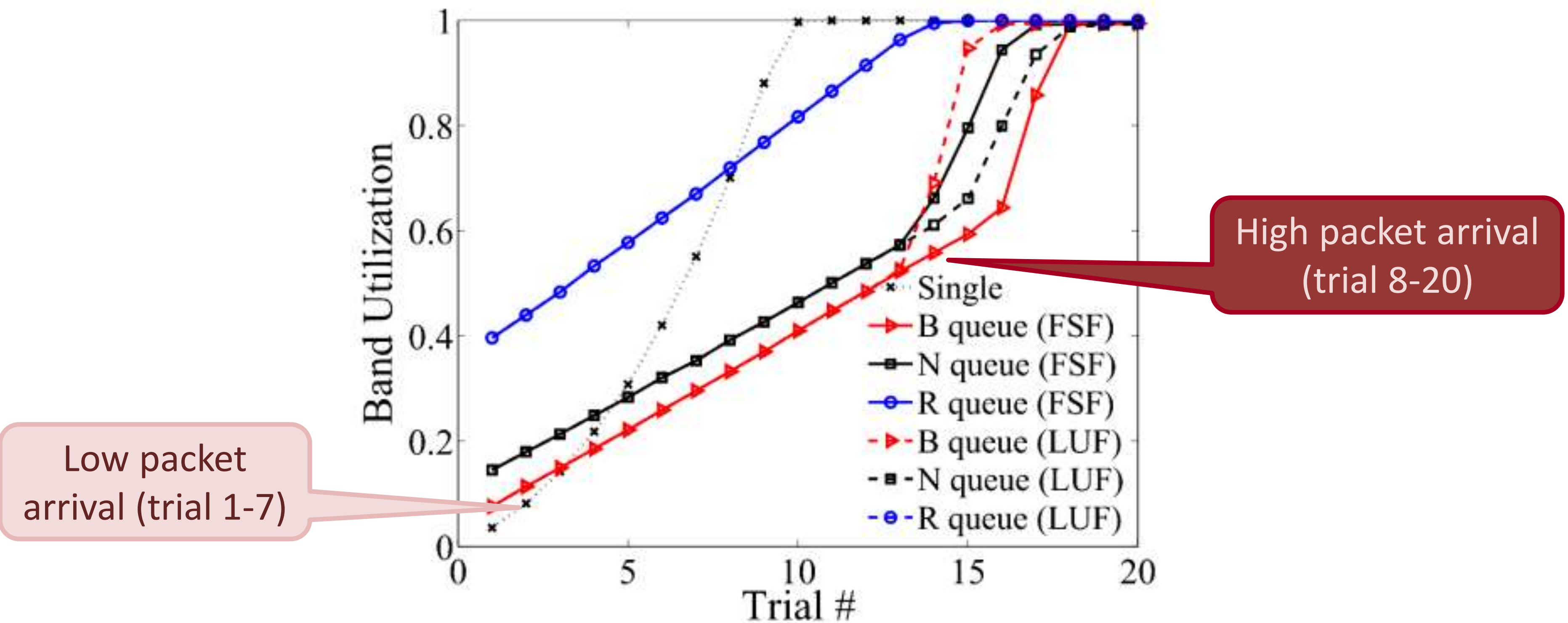
- Simulations with increased arrival rates of all types of traffic to observe the impact of heavy traffic on the multi-band system.

- Traffic class arrival rates at different trials:

$$\alpha_B = \{i\}, \alpha_N = \{3i\}, \text{and } \alpha_R = \{10i\} \text{ where } i = 1,2 \ldots, 20.$$

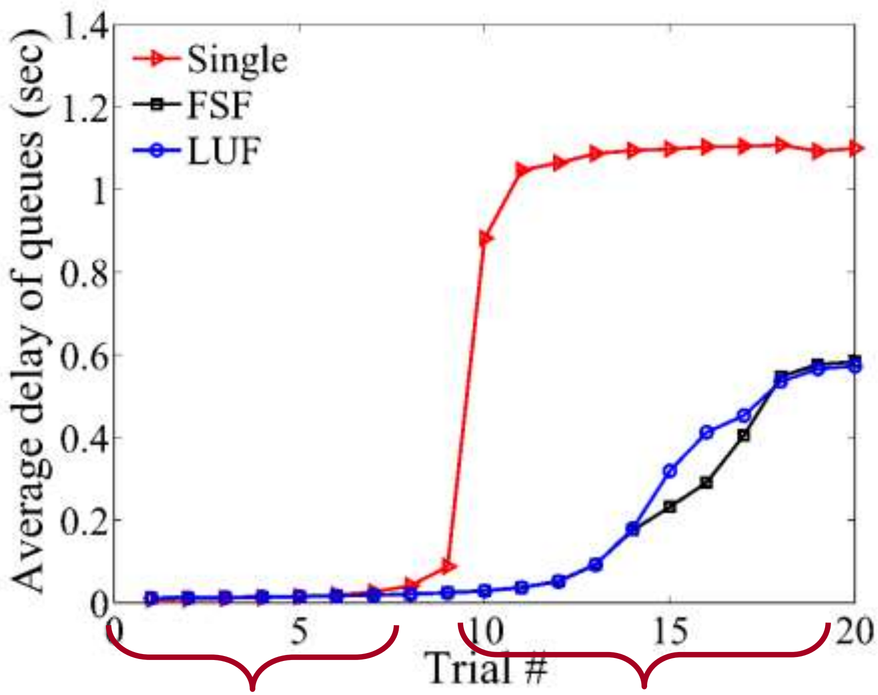
- RT traffic arrival rate is increased at a much higher rate
  - This eventually saturates the R-queue
  - Helps explain the impact of R-quue overflow on performance of the routers.

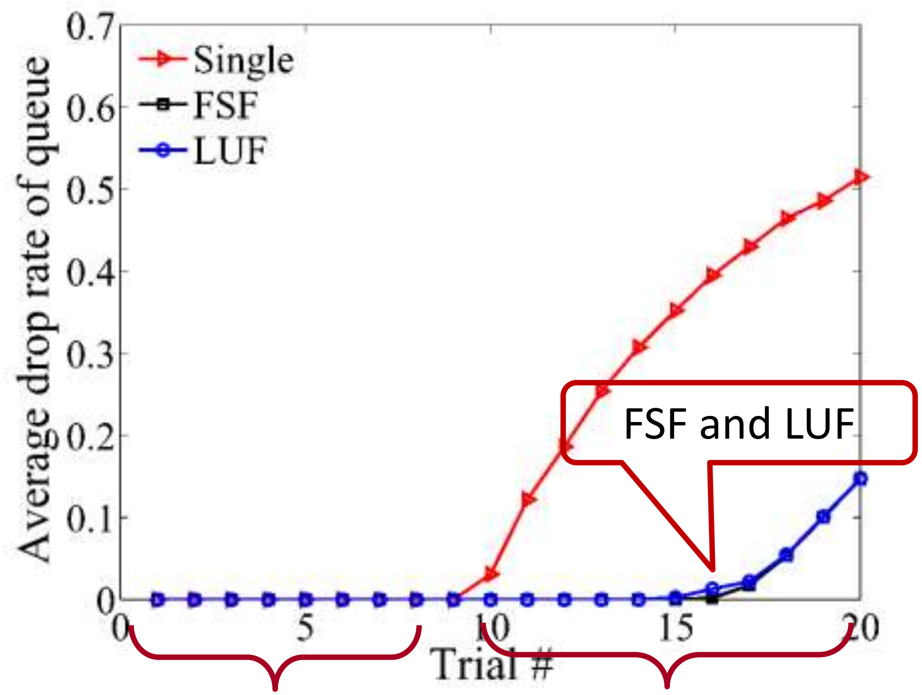
Band Utilization



- Single Band has lower utilization for low arrival rates.
- Multi Band has lower utilization for high arrival rates.
- Both FSF and LUF architecture have similar utilization until trial 13th ($\frac{\alpha_B}{\mu_B} < \frac{\alpha_N}{\mu_N}$).

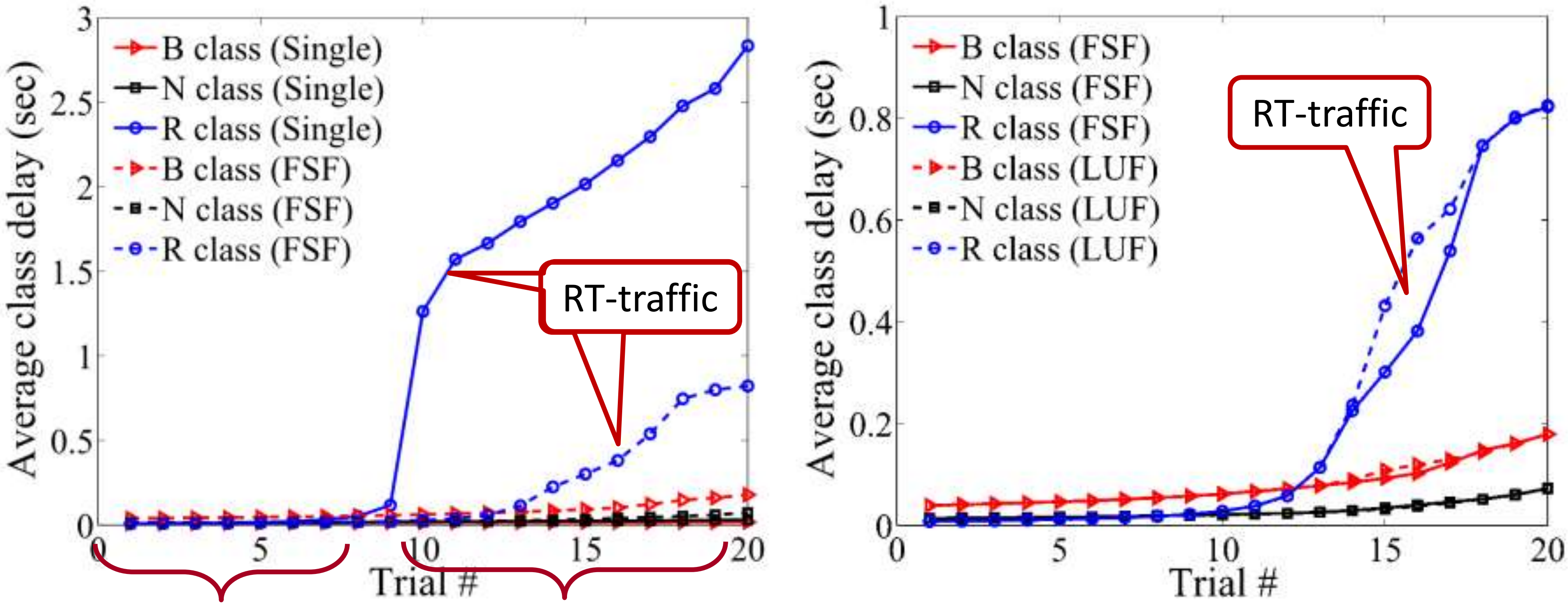
Overall Avg. Delay and Drop Rate of Systems





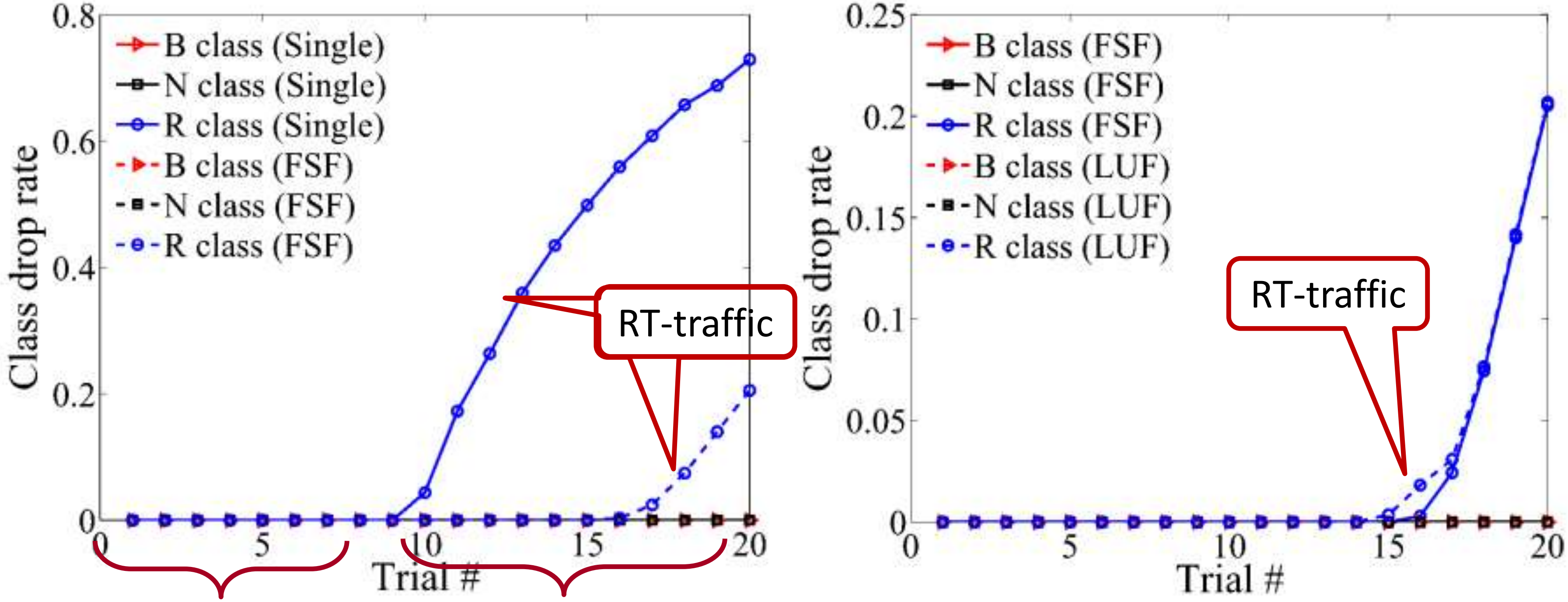
- Delay and Drop rate of Single and Multi bands systems are same for low arrival rates.
- Delay and Drop rate of Single band system is much higher than Multi Band system for high arrival rates.
- Delay and Drop rate of FSF and LUF are almost same but FSF is better for some trial because some packets are waiting less in N-queue than B-queue.

Average Delay of Class Traffics



- Delay of class traffics of Single and Multi bands systems are same for low arrival rates.
- Delay of RT-class traffic of Single band is much higher than Multi band because of lower bandwidth of Single band and high arrival rates.
- Delay of FSF and LUF are almost same but FSF is better for some trial because RT-packets are waiting less in N-queue than B-queue.

Drop Rate of Class Traffics



- Drop Rate of class traffics of Single and Multi bands systems are same and lower for low arrival rates.
- Drop Rate of RT-class traffic of Single band is much higher than Multi band because of lower bandwidth of Single band and high arrival rates.
- Drop Rate of FSF and LUF are almost same but FSF is better for some trial because dropped RT-packets in B-queue are more than ones in N-queue.

Summary of Results

- Performance of multi-band architecture (both allocation policies) is better than single band architecture under heavy traffic.
- Multi-band systems do not use band as efficiently as single band for low traffic.
- FSF allocation policy in multi-band architecture has the best performance.
- The highest priority class in single band can have less delay than same class in multi-band architecture.
- Under heavy traffic, the lower priority class in single band has longer waiting time (in queue) than for multi-band architecture.
- Although FSF has less delay than LUF for RT class, there is no significant difference between throughput of FSF and LUF policies

Conclusion

- We have proposed a novel scheduling algorithm for multi-band mobile routers that exploits band sharing.
- Performance metrics of the proposed multi-band system are presented through different cases for fastest server first allocation.
- Single and multi bands are compared.
- Proposed scheduling algorithm can help network engineers build next generation mobile routers with higher throughput and utilization.

Thank You

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