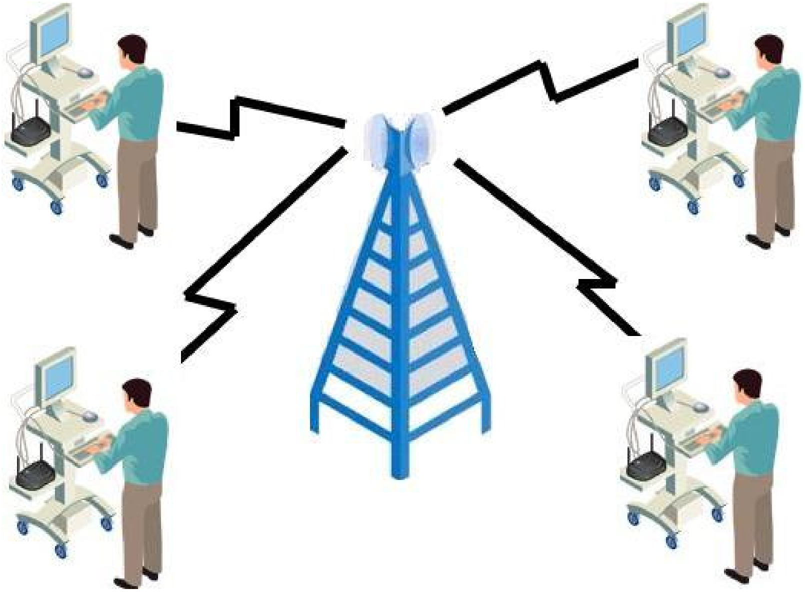
Implementation and Evaluation of a MAC Scheduling Architecture for IEEE 802.16 WirelessMANs



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Outline

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- IEEE 802.16 MAC
- Problem Statement
- Related Work
- Scheduling Architecture
- NS-2 Implementation
- Simulation Analysis
- Conclusions
- Future Work

Motivation

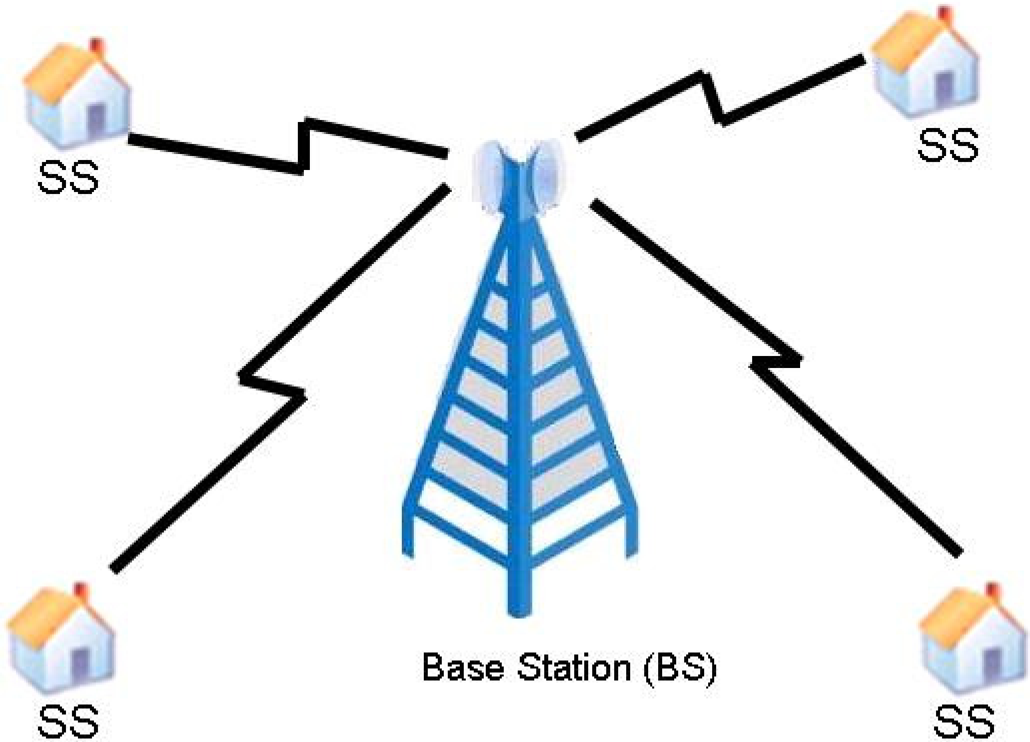
- Features
  - Large spamming area (up 30 miles)
  - Data rate (variable and high up to 75 Mpbs)
  - Large frequency band (2-11 GHz)
  - NLOS
  - Mobility
  - TDD and FDD modes
  - PMP and Mesh networks
  - Half and Full duplex modes
  - Easy deployment

Motivation

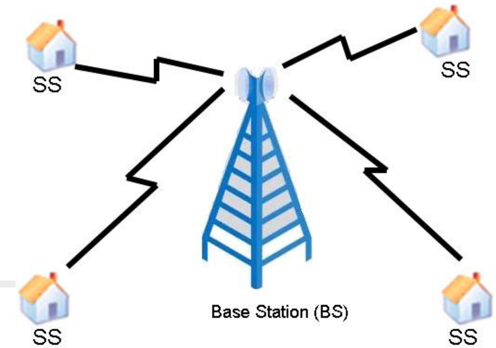
- Applications
  - Disaster recovery places
  - WiFi backhaul
  - QoS for VoIP and other real-time applications
  - Wireless access to rural areas
  - A replacement of DSL
  - Web access at home and commercial places

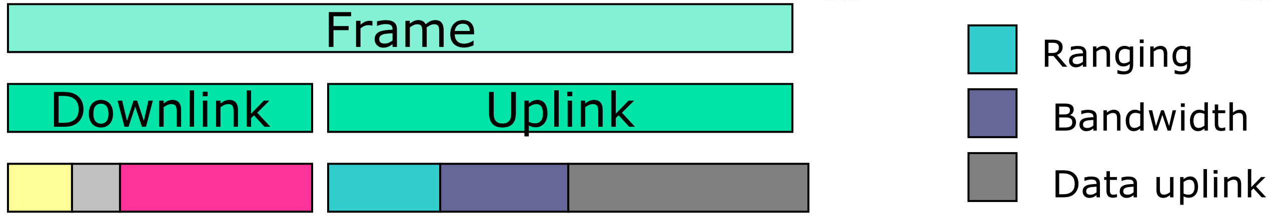
IEEE 802.16 Architecture

- Base Station (BS)
- Subscriber Station (SS)
- Only BS-SS communication
- TDMA MAC style
- Uplink (SS to BS) and Downlink (BS to SS)



IEEE 802.16 MAC





- Connection formation through management messages
- Request-Grant mechanism for slot allocation
- Slots are specified in UL-MAP
- Each SS sends data in specified slots
- Three ways – contention, piggyback and use granted slots

Problem Statement

- Scheduling Architecture for slots allocation
- Evaluation of scheduling architecture
- Comparative performance analysis with and without bandwidth contention period

Why simulations

- Deployed architecture is not available
- Easy and fast first level testing through simulations

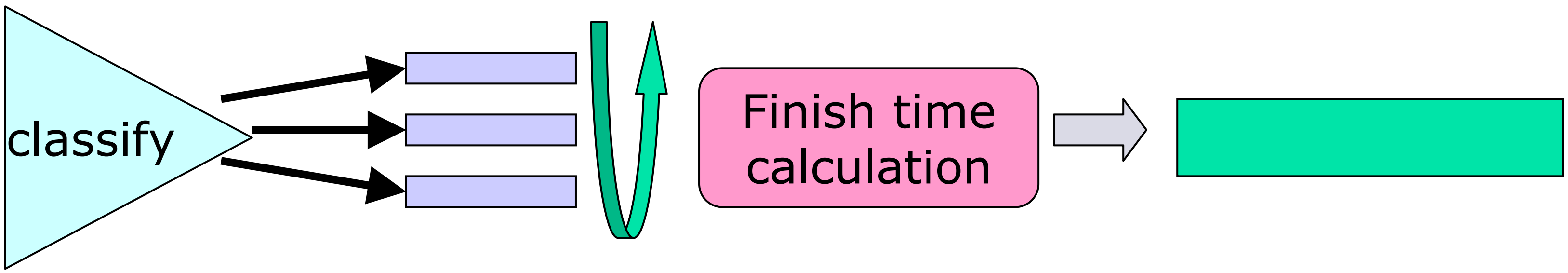
IEEE 802.16 MAC QoS

- Four Flows types
  - UGS – CBR traffic (VoIP without silence)
  - rtPS – VBR traffic (VoIP with silence, video traffic)
  - nrtPS – non real-timer traffic (FTP)
  - BE – traffic with no QoS (telnet, http)
- Slots allocation
  - GPC – per connection bandwidth allocation
  - GPSS – per SS bandwidth allocation

Related Work

- Supriya (05) – Qualnet, GPSS, weighted max-min fair allocation (uplink) and WFQ (downlink) with constant weight
- Chu(02) – GPSS, WRR (uplink) without mentioned weights, No results
- Hawa(02) – PWFQ without priority and weight mentioned
- Moraes(05) – SSs priority, Transmission + TDMA, two versions for uplink slots
- Ganz(03) – strict priority with overall bandwidth allocation module
- Oh(05) – optimal contention period, 2 times the number of users, one b/w request in each frame

Weighted Fair Queuing (WFQ)



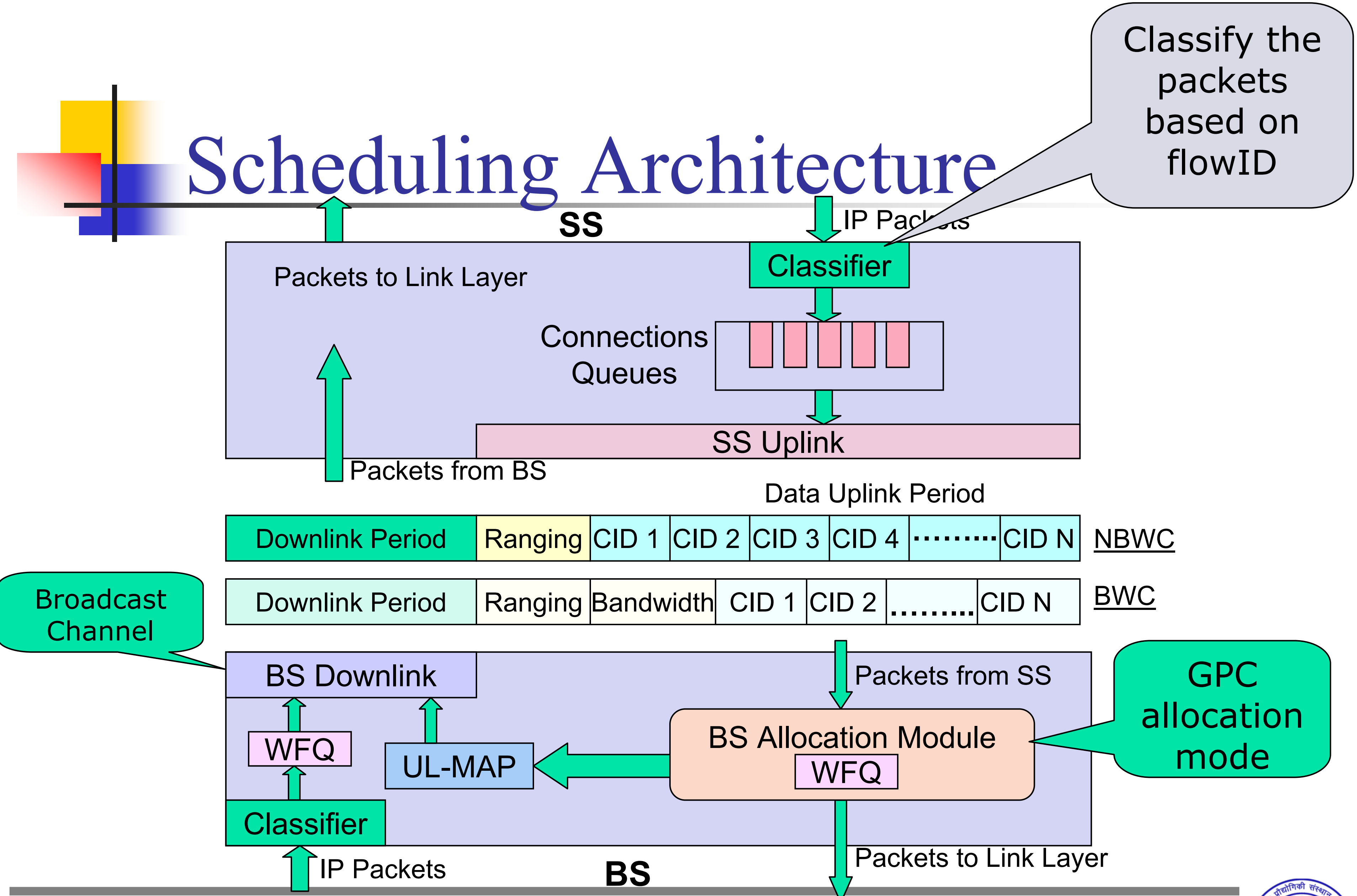
- Bit-by-bit round robin
- F(i,k,t) = max{F(i,k-1,t),R(t)}+P(I,k,t)/w(i)
- Round number – the index of round in bit-by-bit round robin scheduling
- Packet served in finish time order
- Update round number on each packet arrival or departure
- Scheduling is done based on weights and length of flow queue

Scheduling Architecture

- Design Goals
  - Delay bound for real-time (UGS and rtPS flows) traffic
  - QoS to all applications (number and type of flows only matters)
  - GPC slots allocation mode
  - Easy to implement

- Design Decisions
  - WFQ as downlink and uplink scheduling algorithm
  - Bit-wise-bit fair allocation
  - Guarantee time bound on packet transmission
  - Protects responsive flows against unresponsive flows also called flow isolation

Scheduling Architecture



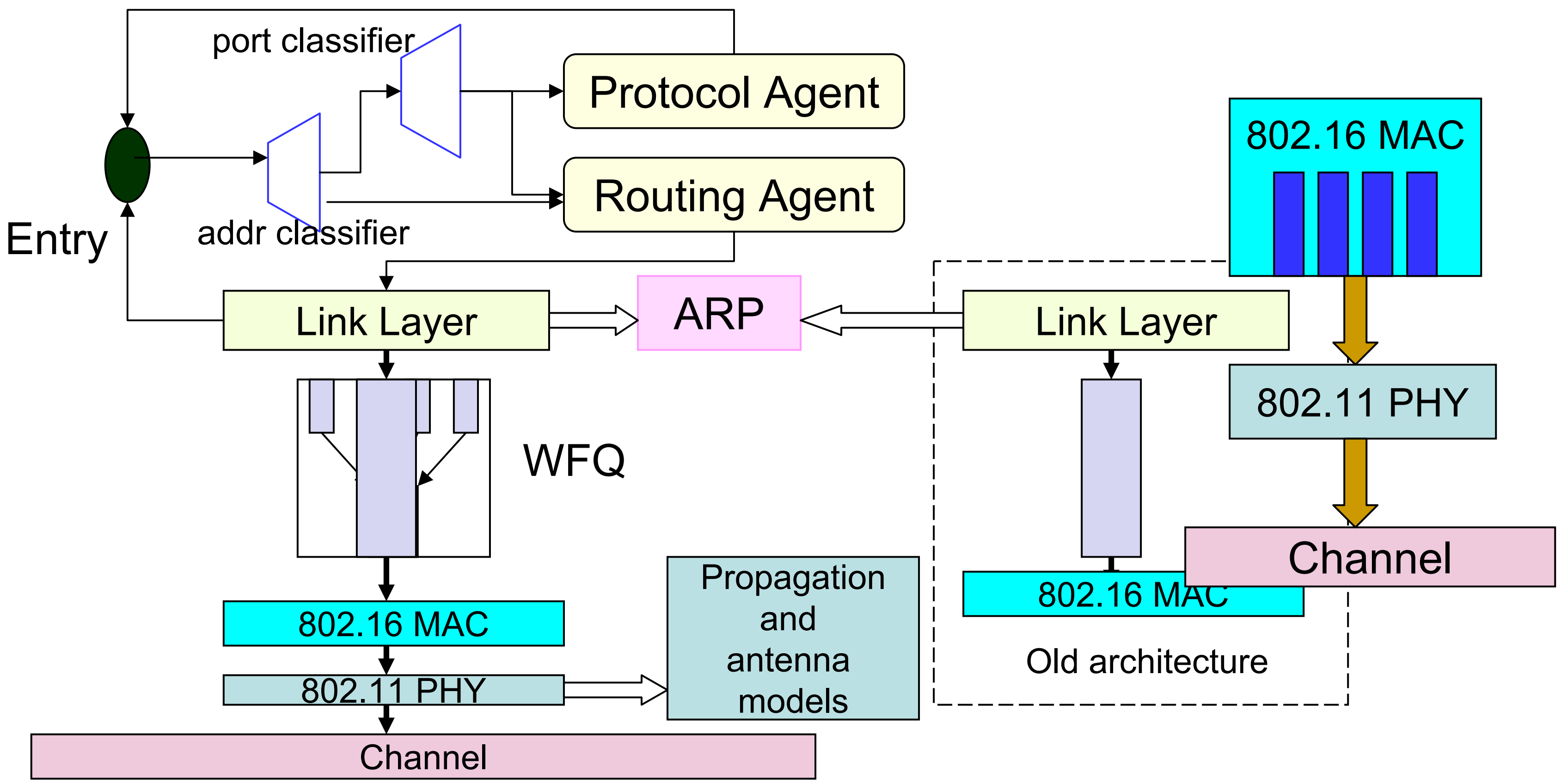
Other Details

- Each SS can have as many flows and maintains the same number of MAC level queues
- BS has only one MAC level queue
- Admission control
- Forever loop and polling time
  - Connections do not have any packets
  - BS does not allocate slots for connections
  - Polling time – Every connection should be able to communicate its queue information to BS within this time
  - Unicast request slots from ranging period
  - Choice of polling time depends on number and types of flows and their weights

NS-2 Implementation Details

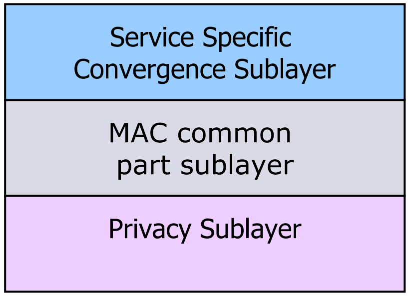
- Supported features
  - Interface between MAC and LL
  - TDD frame structure
  - GPC mode bandwidth allocation
  - RANG-REQ, REG-REQ, BW-REQ, CONN-REQ
  - RANG-RSP, REG-RSP, CONN-RSP
  - IEEE 802.16 MAC frame structure
  - All four uplink scheduling services
  - MAC level packet association based on flowID

Modified NS-2 Node



Simulation Analysis

- Assumptions
  - Only IEEE 802.16 MAC CPS layer
  - No DCD and UCD
  - No guard timer for synchronization
  - No admission control
  - No ARQ/ACK mechanism
  - IEEE 802.11 PHY layer



- What we want to evaluate
  - Effect of one type of flow on other type of flow
  - Comparative performance analysis of BWC and NBWC modes
  - Choice of bandwidth contention period for BWC mode

Flow Specifications and Weights

- UGS – CBR traffic with 28 Bytes packet and 22.4 Kbps rate (G.729 codec)
- rtPS – Video traces with 64 Kbps (H.263 codec)
- nrtPS – FTP traffic from ns-2
- BE – Telnet traffic from ns-2
- Weights are in the ratio of minimum reserved bandwidth of flows

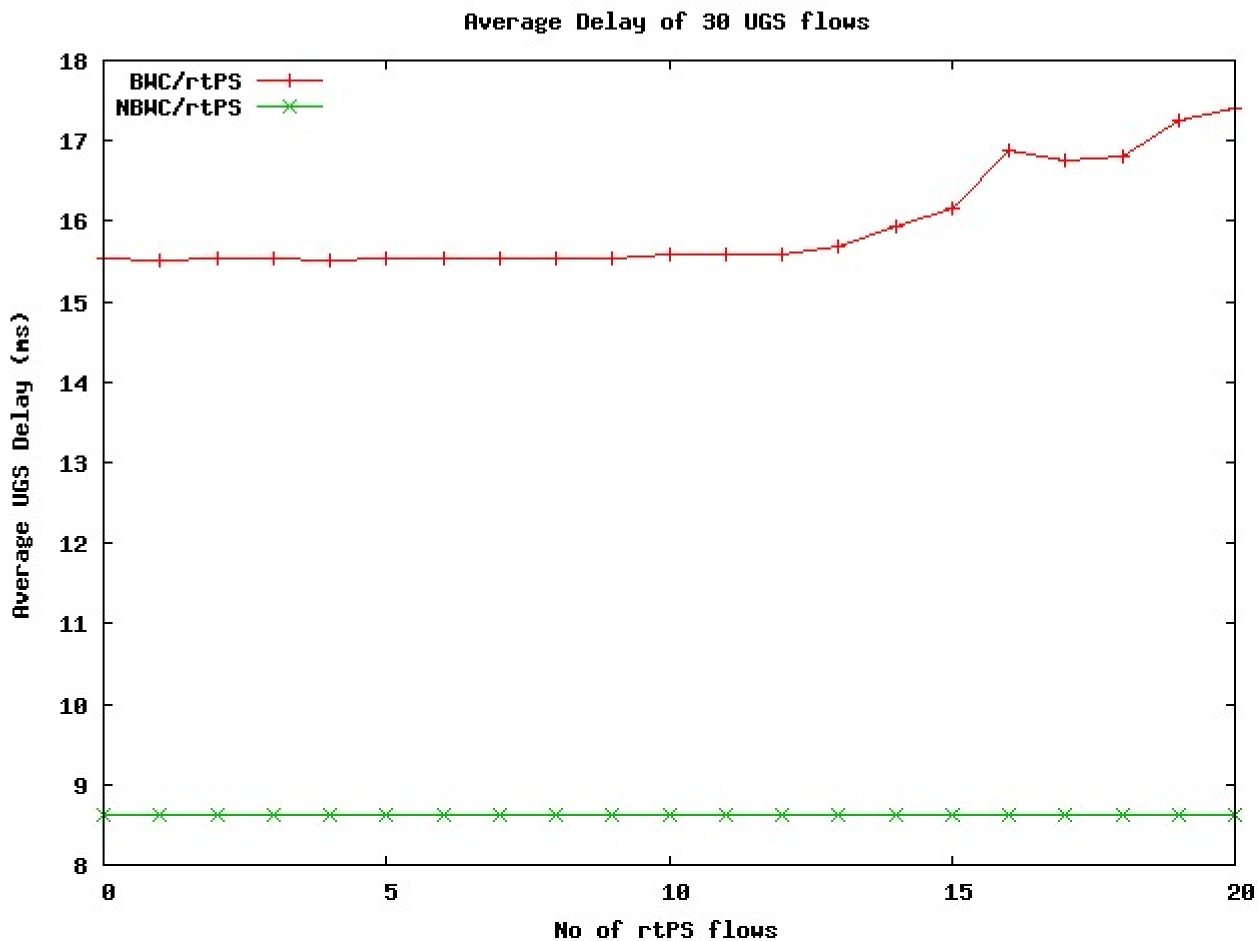
UGS	22.4
rtPS	64.0
nrtPS	100.0
BE	10.0

Parameter Choices (uplink flows)

Data rate	11 Mbps
Basic rate	1 Mbps
Slot time	8 micro sec
Frame length	10 msec
Uplink frame	8 msec
Downlink frame	2 msec
Ranging period	100 slots (=0.8 msec)
Bandwidth contention	100 slots (=0.8 msec)
Data uplink slots (BWC)	800 slots (=6.4 msec)
Data uplink slots (NBWC)	900 slots (=7.2 msec)

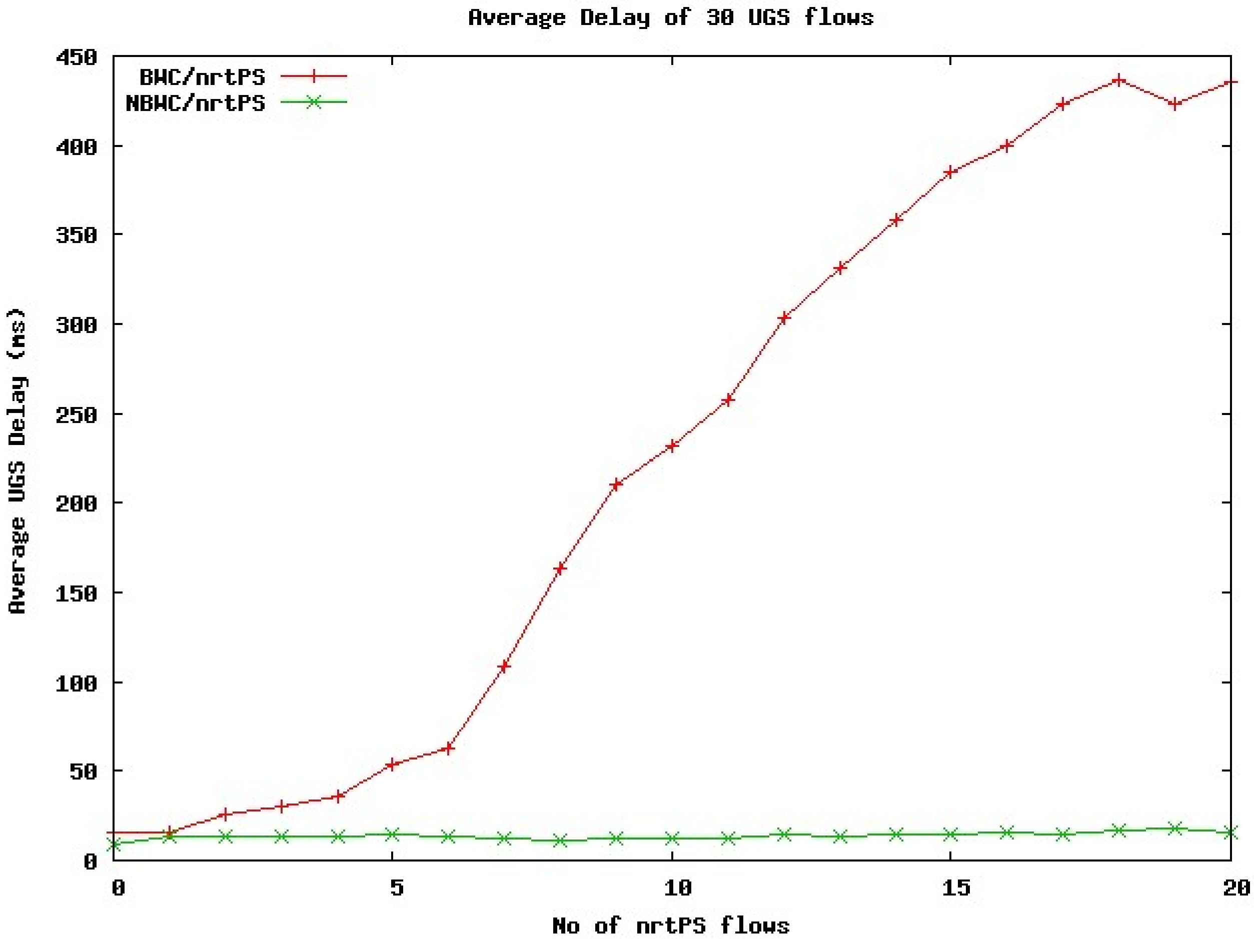
Delay Analysis of UGS flows

- UGS delay increases after a fix number of rtPS flows
- UGS flows are not able to send queue information to BS in contention manner



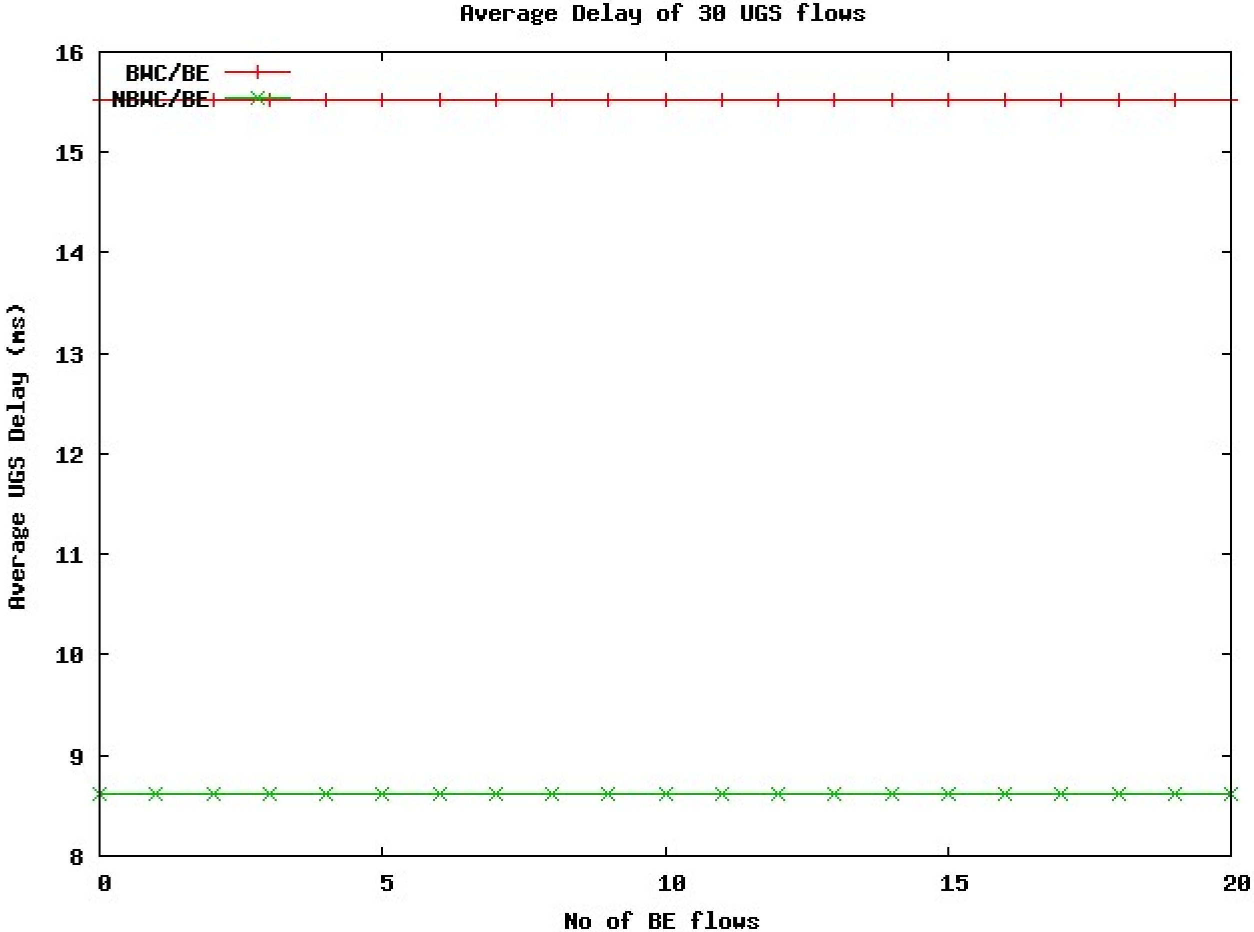
Delay Analysis of UGS flows

- Increment in delay is linear for nrtPS flows
- UGS queues relatively non-active than nrtPS queues



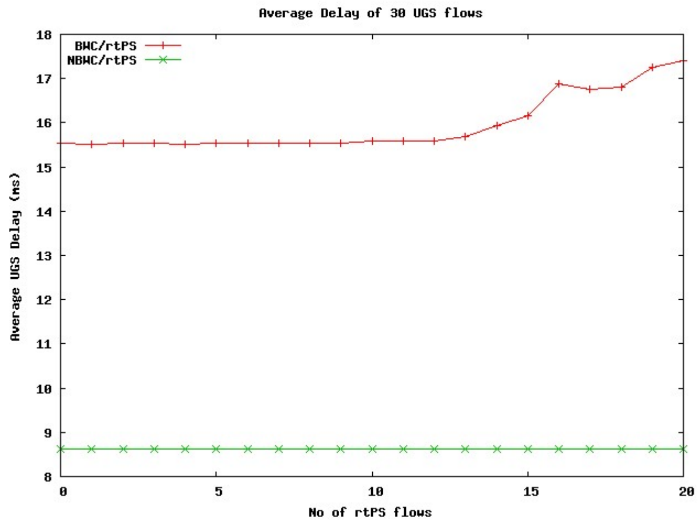
Delay Analysis of UGS flows

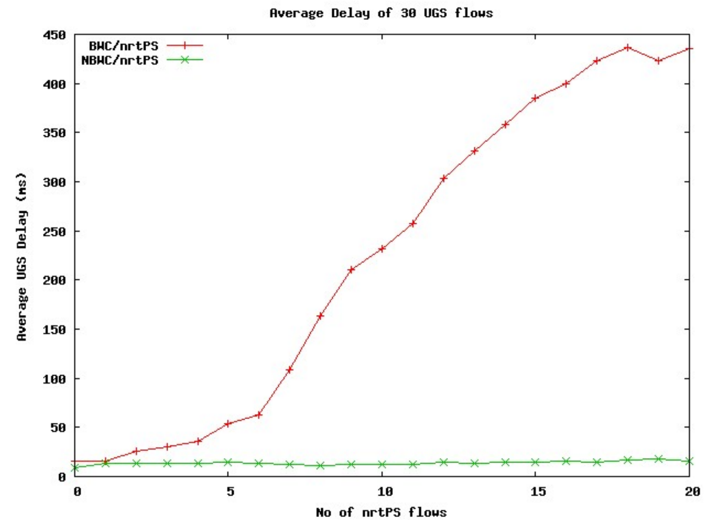
- UGS delay is constant with BE flows
- Packets are very rare in BE flows thus fewer BE connection take part in contention

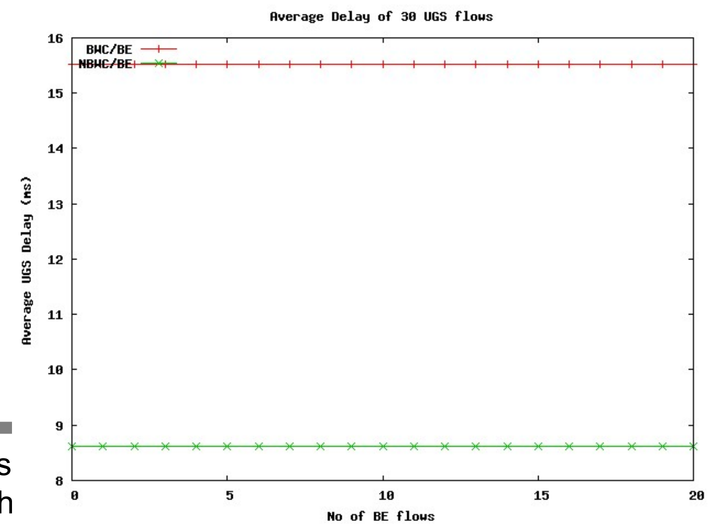


Delay Analysis of UGS flows

- UGS delay is more affected by nrtPS flows

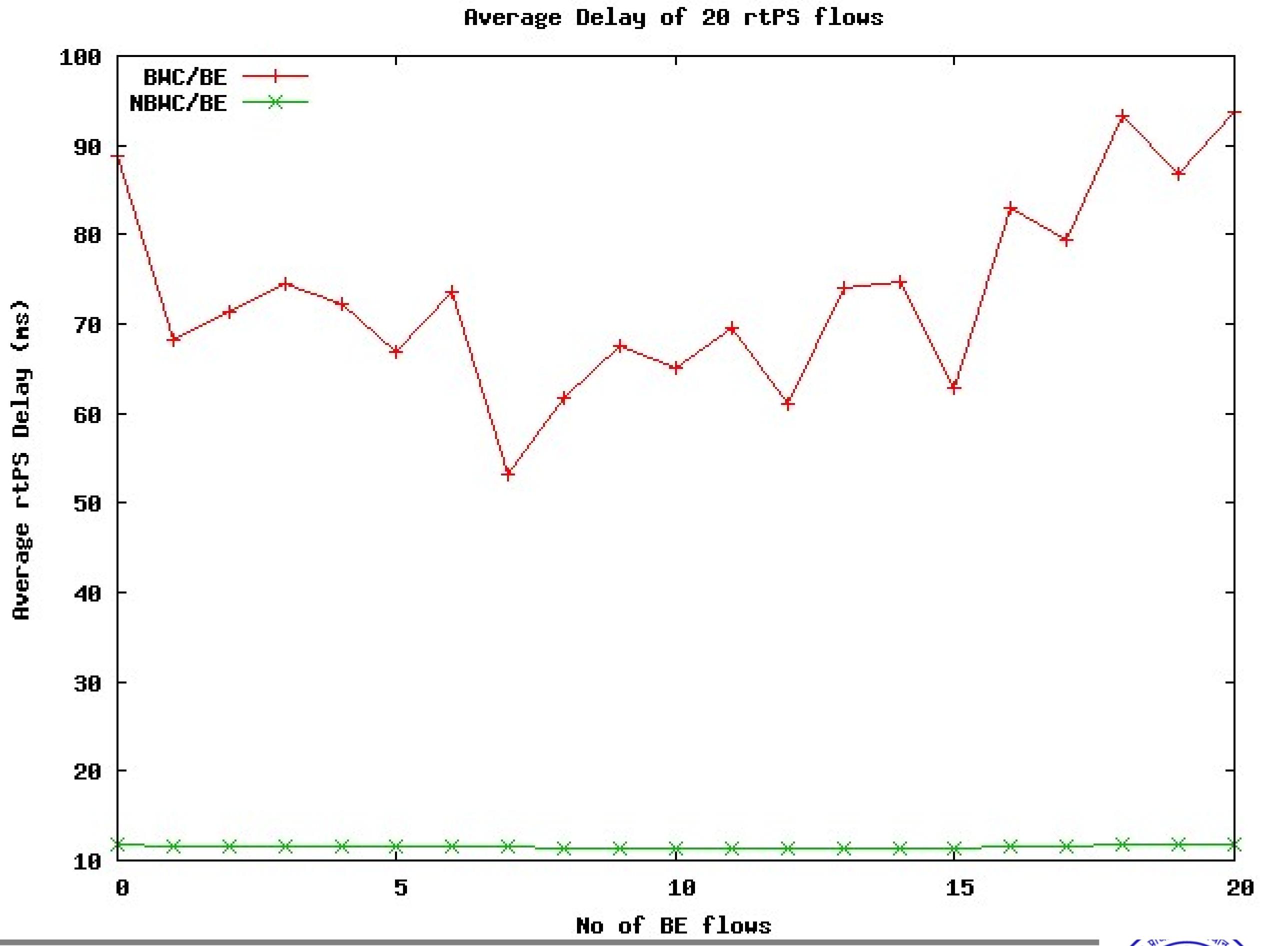




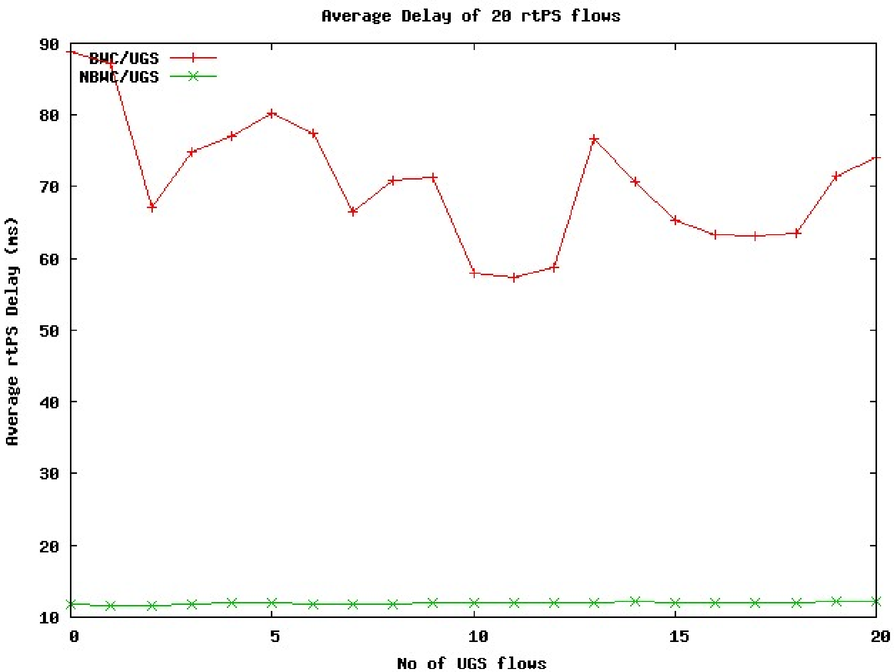


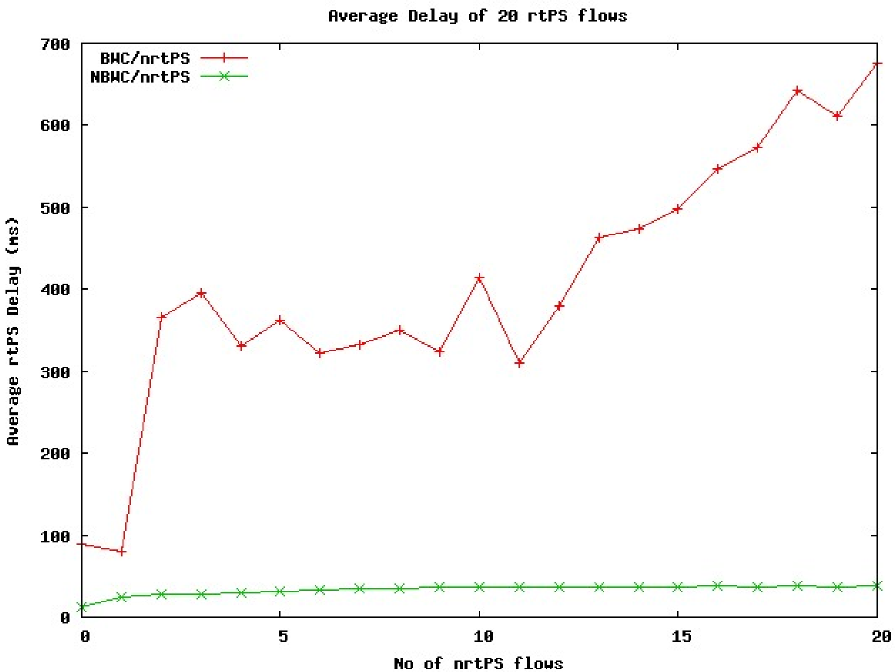
Delay Analysis of rtPS flows

- rtPS delay is irregular but lies in a certain range
- rtPS flows needs more slots to convey queue information to BS



Delay Analysis of rtPS flows

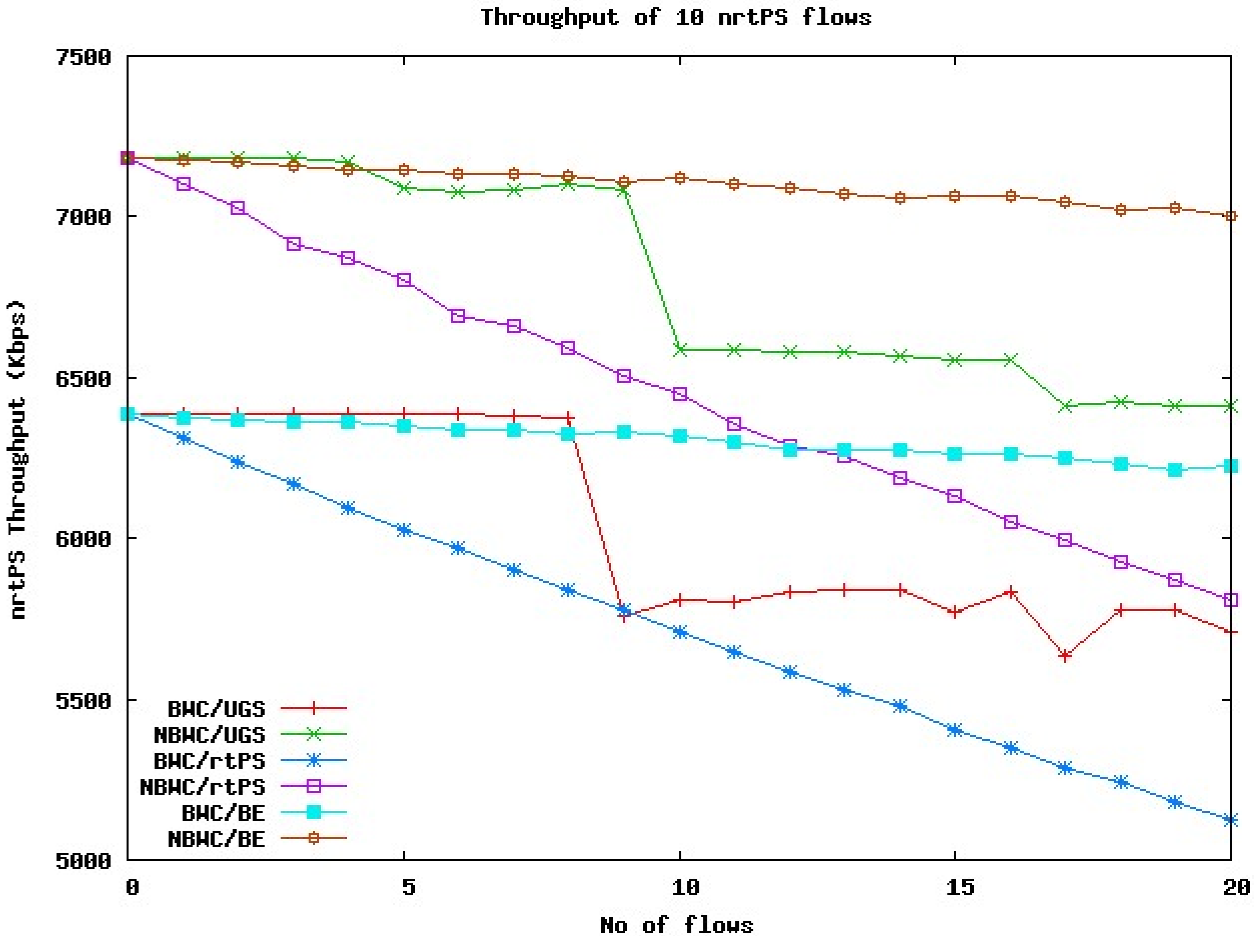




- rtPS delay increases in NBWC mode also with nrtPS flows
- rtPS delay increases linearly after a certain number of nrtPS flows in BWC mode

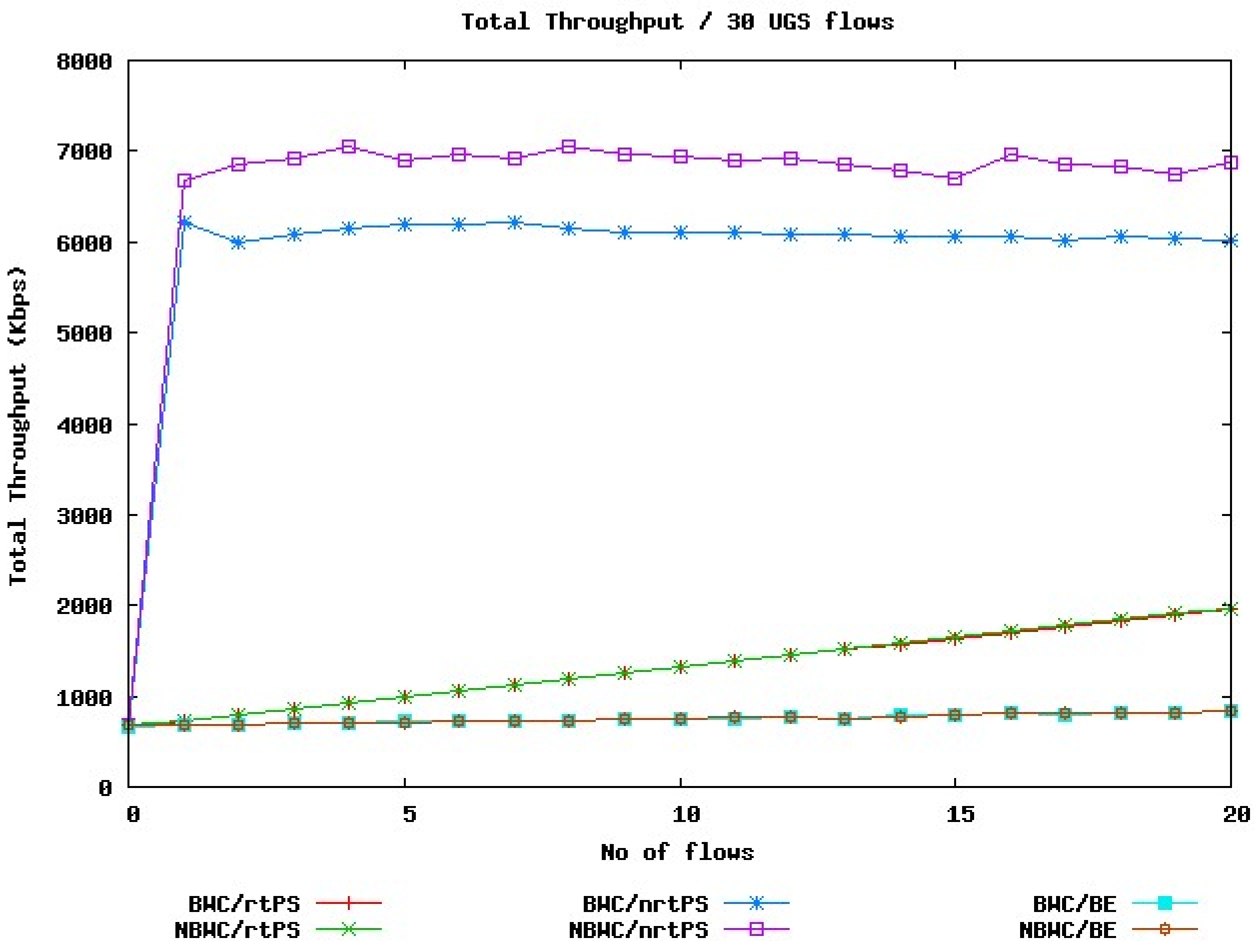
Throughput Analysis of rtPS flows

- With UGS flows sudden decrement in throughput then stable
- UGS flows occupy the slots which were previously allocated to nrtPS flows



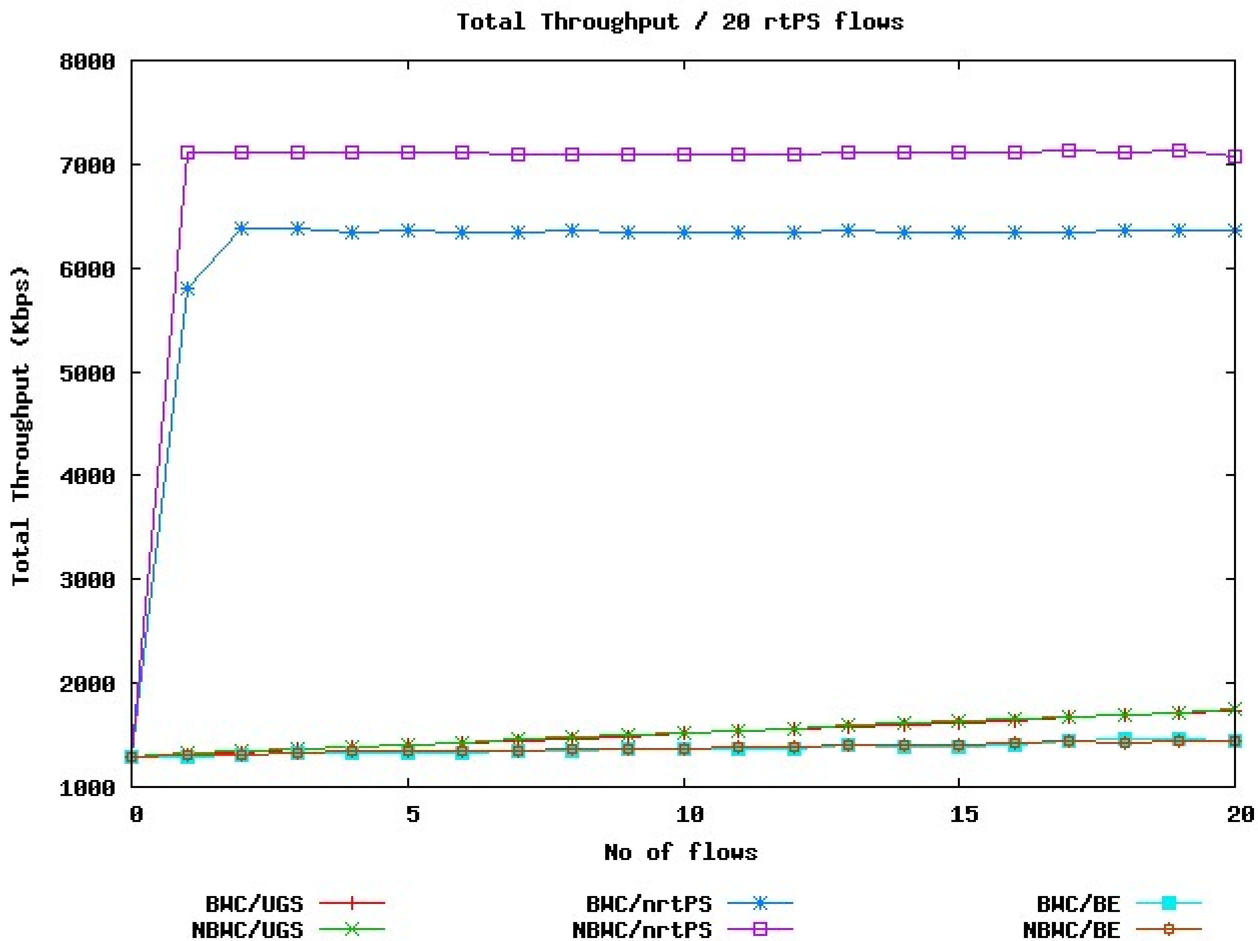
Total Throughput in BWC and NBWC modes

- For rtPS and BE flows total throughput is same
- For nrtPS flows NBWC mode throughput is higher



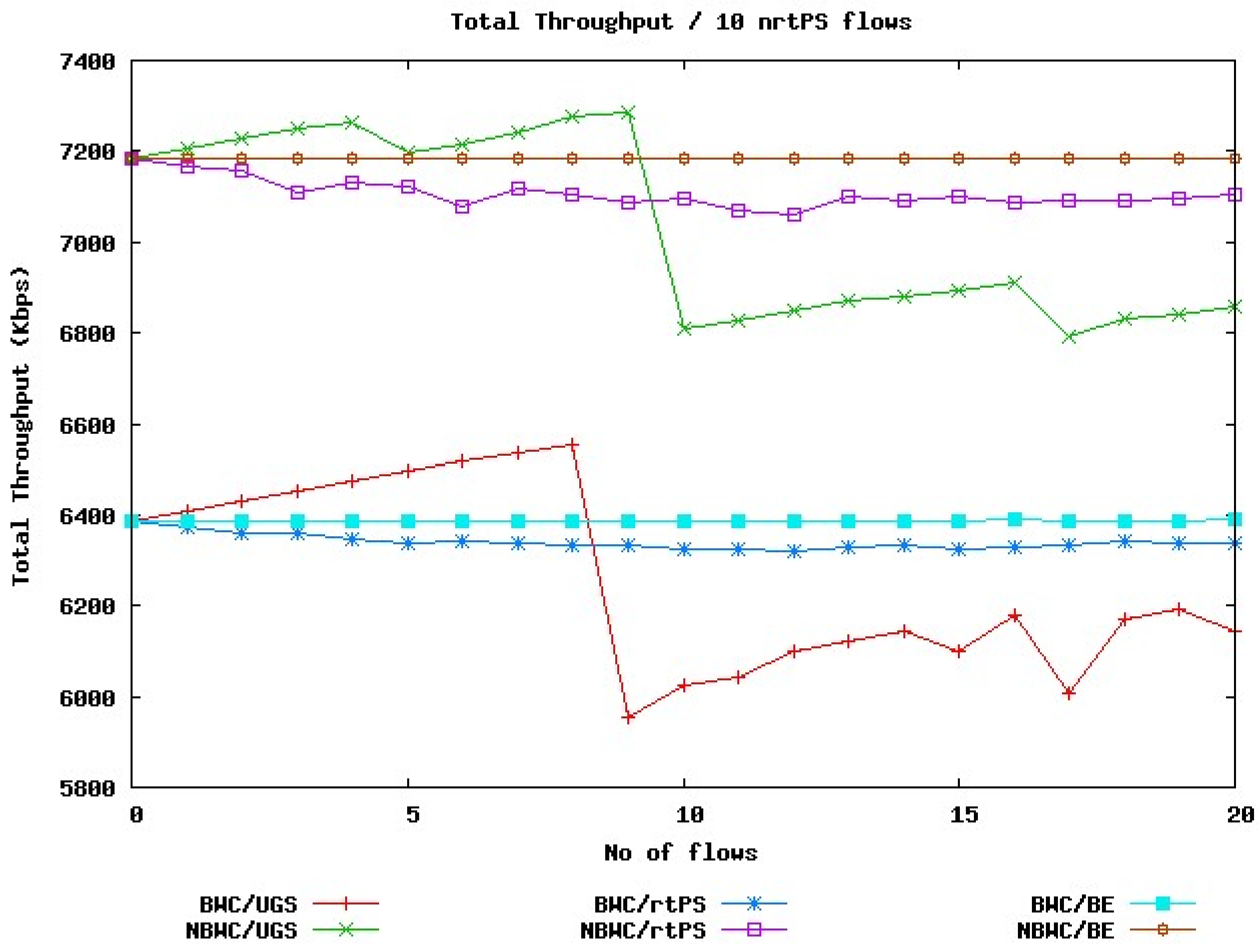
Total Throughput in BWC and NBWC modes

- Total throughput achieved for nrtPS flows is more in NBWC mode

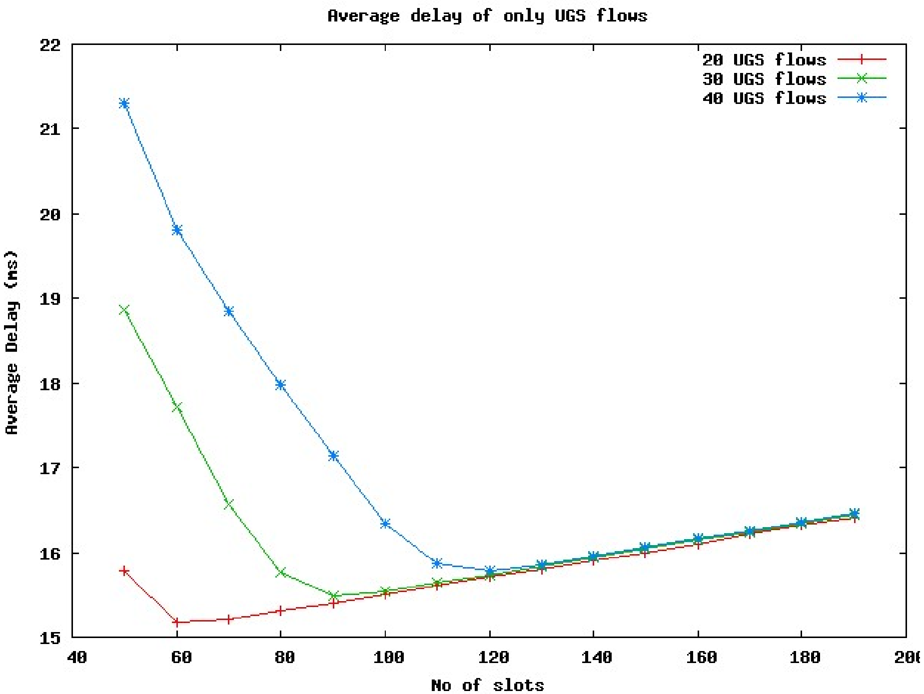


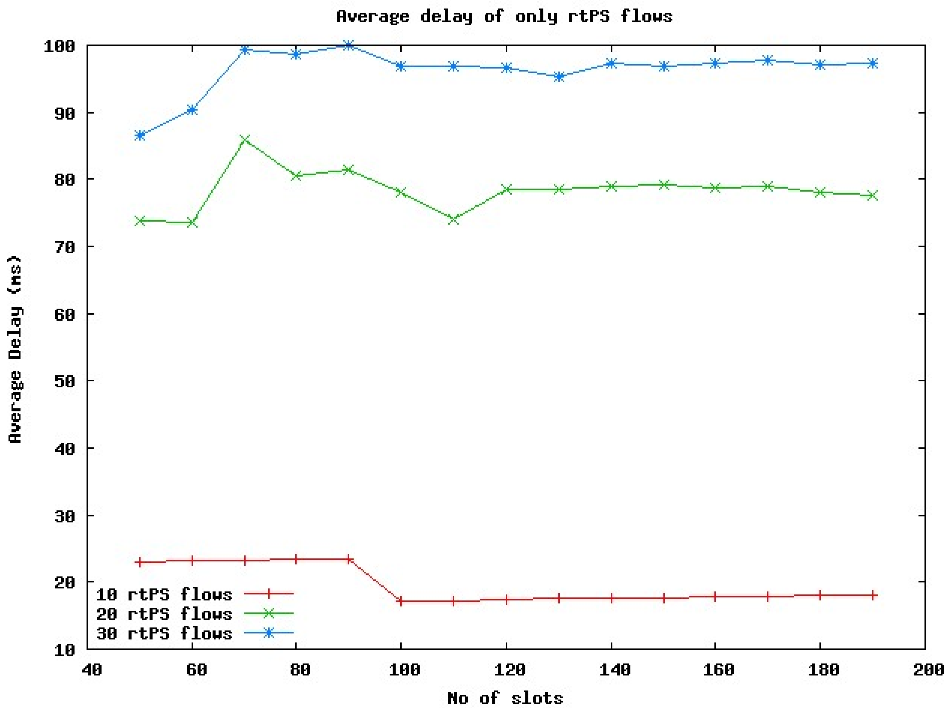
Total Throughput in BWC and NBWC modes

- Similar to throughput of nrtPS flows graph
- Throughput of NBWC mode is higher than BWC mode



Optimum value of Bandwidth Contention





- For 30 UGS flows delay is minimum at 100 slots
- rtPS delay is not very regular

Comparison between BWC and NBWC modes

- Average UGS delay
  - Almost constant but higher in BWC mode with BE flows
  - Linear increase with nrtPS flows but with higher slop in BWC mode
  - Almost constant up to a certain number of rtPS flows than linear increment in BWC mode while constant in NBWC mode
- Average rtPS delay
  - Irregular delay behavior of rtPS flows in BWC mode
  - Delay is more in BWC mode in all cases

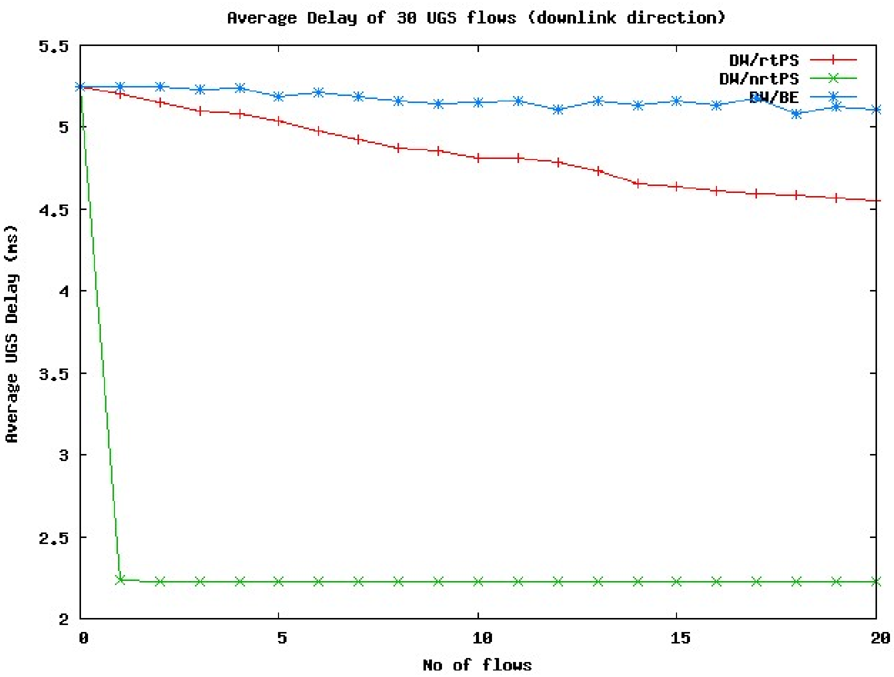
Comparison between BWC and NBWC modes

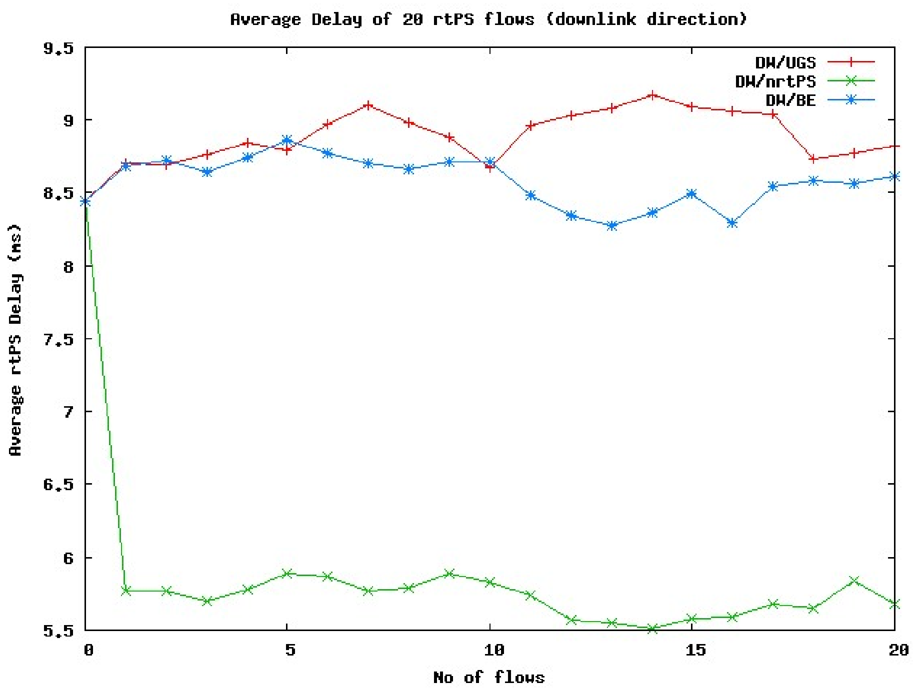
- nrtPS throughout
  - Decreases linearly with rtpS and BE flows in both modes
  - Sudden decrement then stable with UGS flows in both modes
- Total throughout
  - Similar to nrtPS throughput
  - Almost constant with BE flows in both modes
  - Lies in certain range with rtPS flows in both modes
  - Sudden decrement then stable with UGS flows in both modes
- NBWC mode perform better or equivalent with BWC mode

Parameter Choices (downlink flows)

Data rate	11 Mbps
Basic rate	1 Mbps
Slot time	8 micro sec
Frame length	10 msec
Uplink frame	2 msec
Downlink frame	8 msec
Ranging period	25 slots (=0.2 msec)
Bandwidth contention	25 slots (=0.2 msec)
Data uplink slots (BWC)	200 slots (=1.6 msec)
Downlink slots	1000 slots (=8.0 msec)

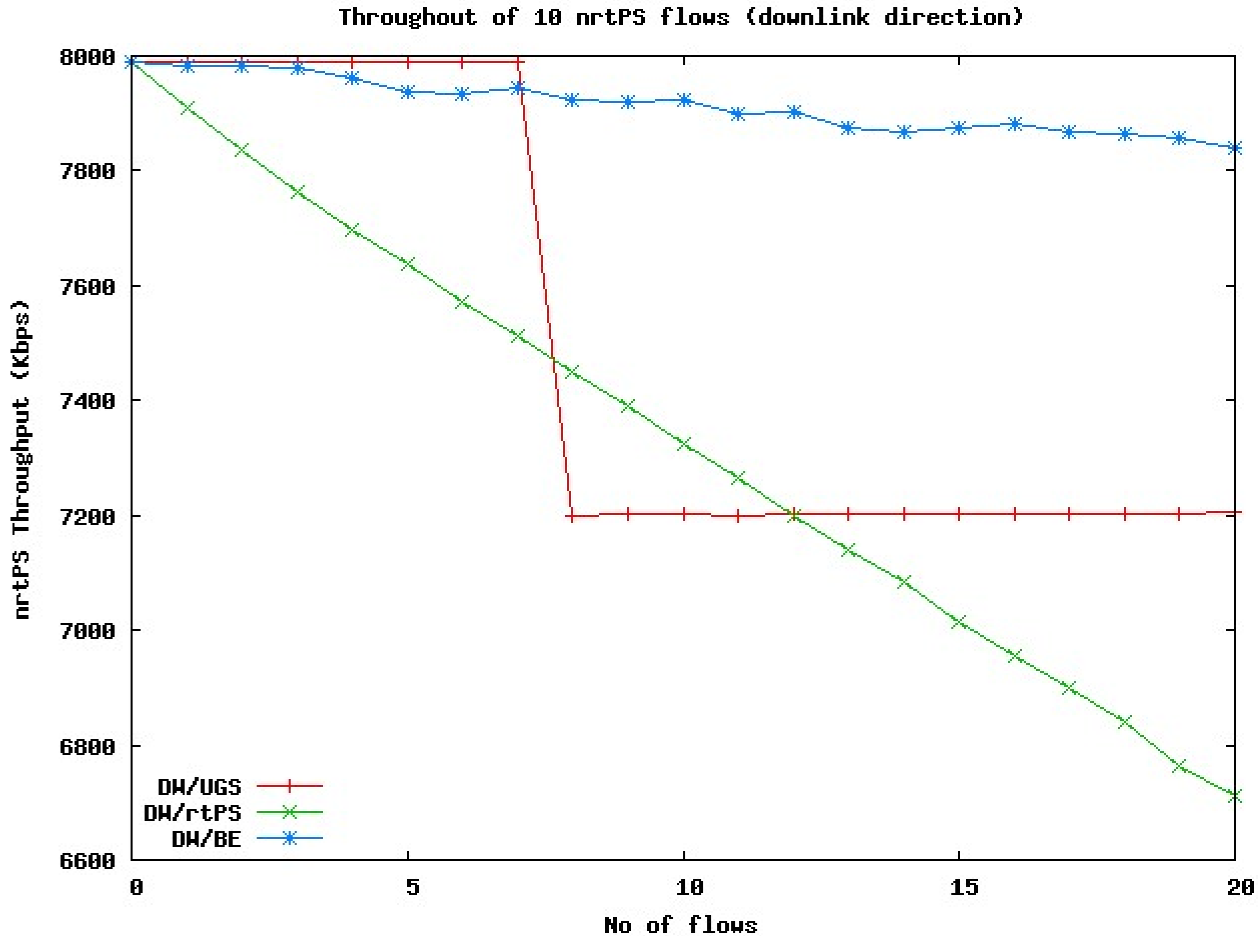
Delay Analysis





Throughput Analysis

- Expected output
- Linear decrement with BE and rtPS flows
- Sudden decrement then stable with UGS flows



Conclusions

- Simple approach
  - Only minimal required modules
  - WFQ well known for 20 decades now
  - One module with two copy
- NBWC mode
  - completely remove the bandwidth contention period
  - Remove the possibility of collision at BS
  - Overhead is less compared to BWC mode
- Performance
  - Delay is less in all case in NBWC mode
  - Throughput is higher because of removal of bandwidth contention period
- Drawback
  - Forerver loop
  - Polling time concept

Future Work

- ARQ/ACK mechanism implementation
- Fragmentation
- HTTP traffic as BE flow
- Classification of packets
- Order of bandwidth contention period
- Polling time calculation
- Dynamic variation in framesize

Acknowledgements

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Thank You ☺

Questions ?