Performance of Bandwidth and QoS Aware LTE Uplink Scheduler Towards Delay Sensitive Traffic

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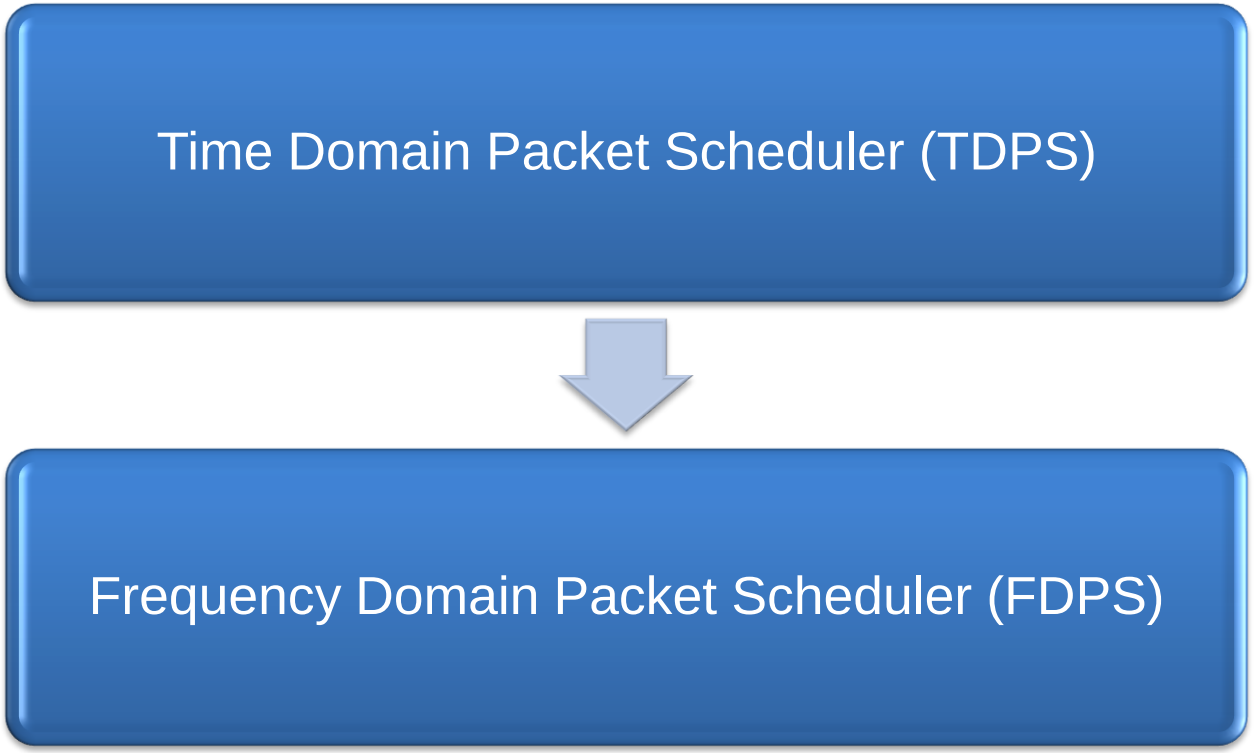
Contents

Introduction

- Long Term Evolution (LTE) air interface
  - Orthogonal Frequency Division Multiple Access (OFDMA) for downlink
  - Single Carrier Frequency Division Multiple Access (SC-FDMA) for uplink
- LTE scheduling
  - Allocation of time and frequency resources to users
  - Consider Quality of Service (QoS), channel conditions, fairness, buffer size
- Uplink scheduling constraints
  - Contiguous Physical Resource Blocks (PRBs) allocation
  - Power Control (PC) based allocation
- Delay sensitive traffic
  - Stringent delay requirements
  - Scheduling according to QoS demands

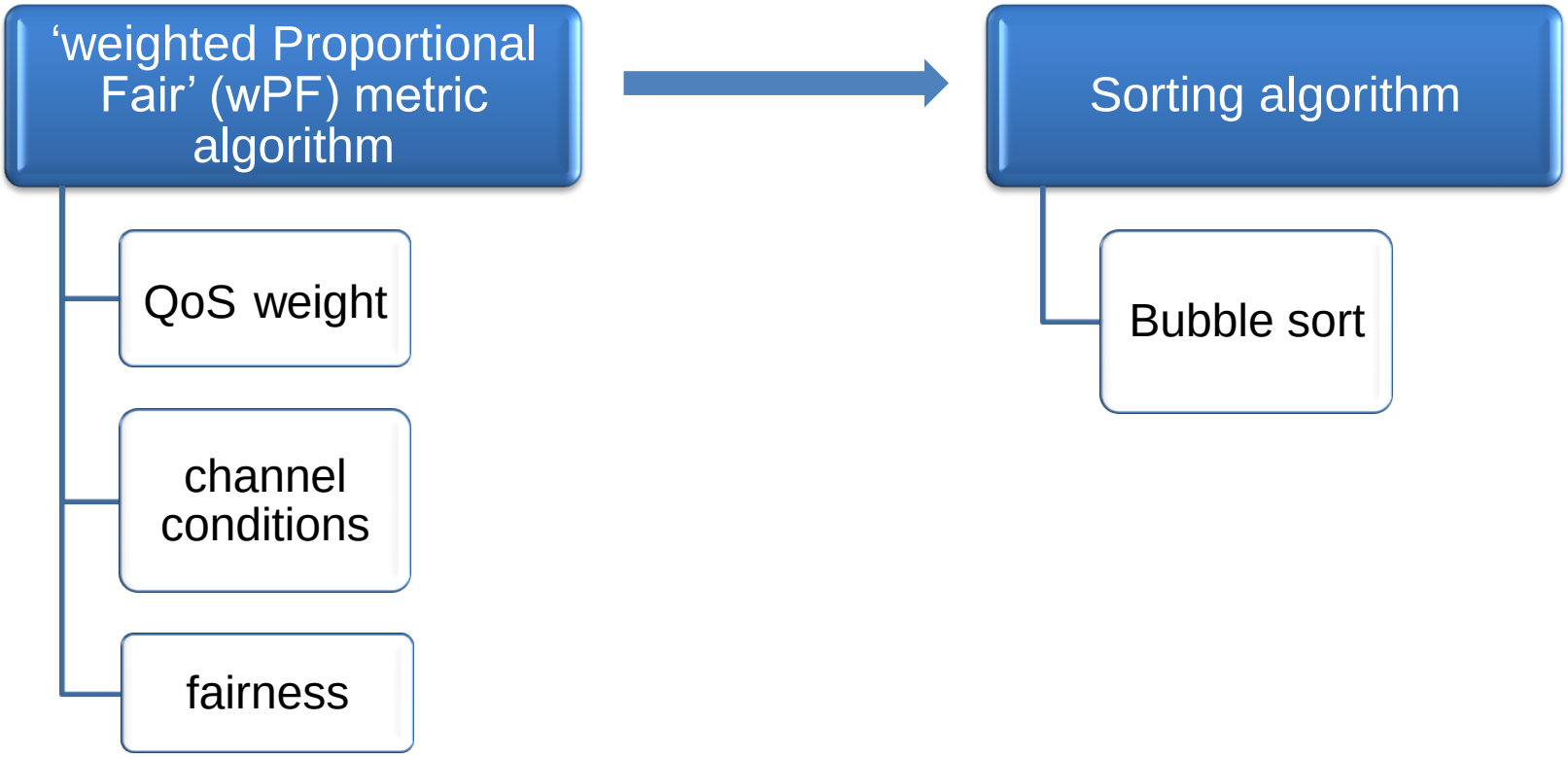
Scheduler Overview



TDPS Metric


‘weighted Proportional Fair’ (wPF) metric algorithm
Sorting algorithm

TDPS Metric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QoS weight
channel conditions
fairness
Sorting algorithm
Bubble sort

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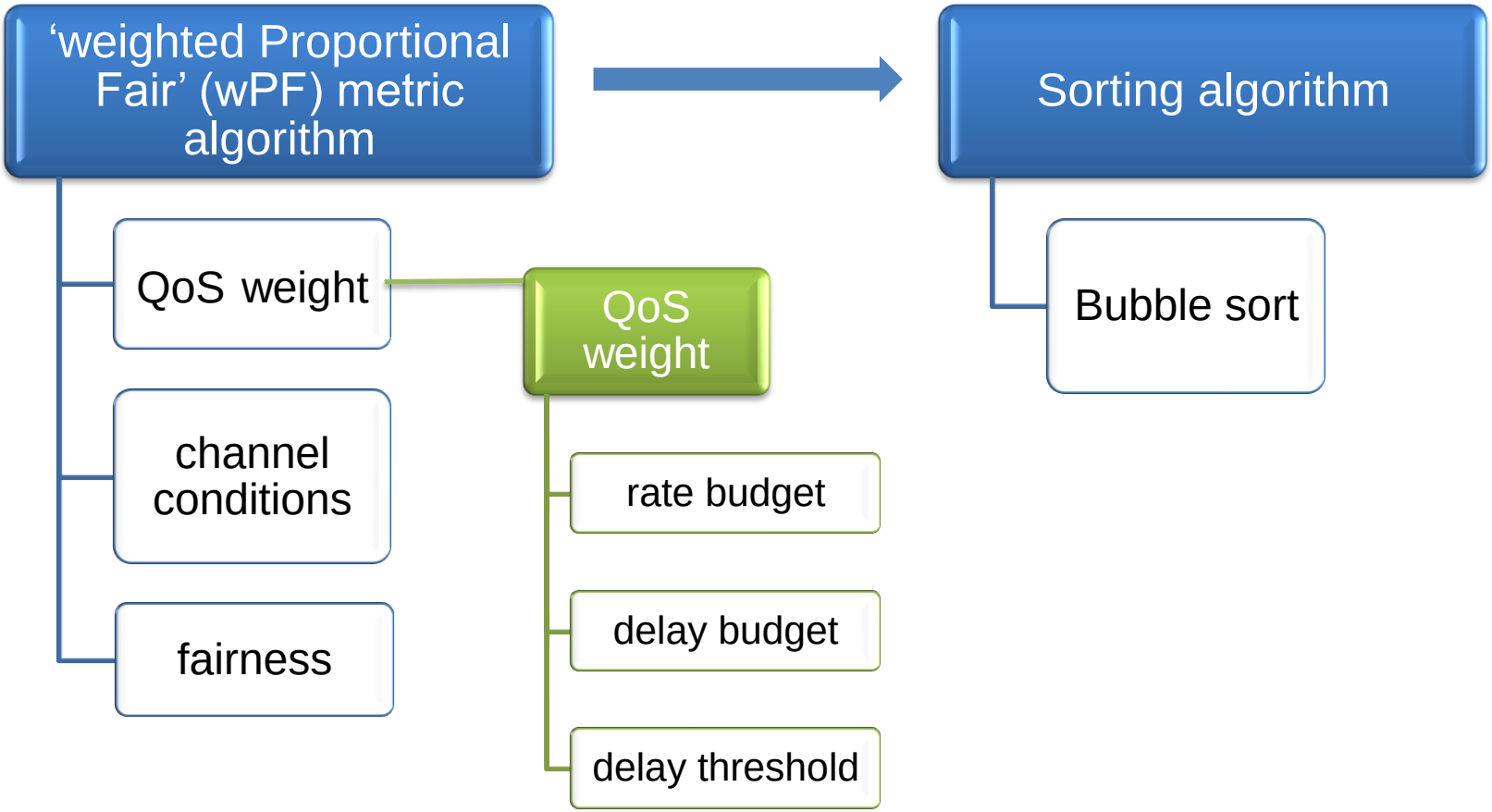
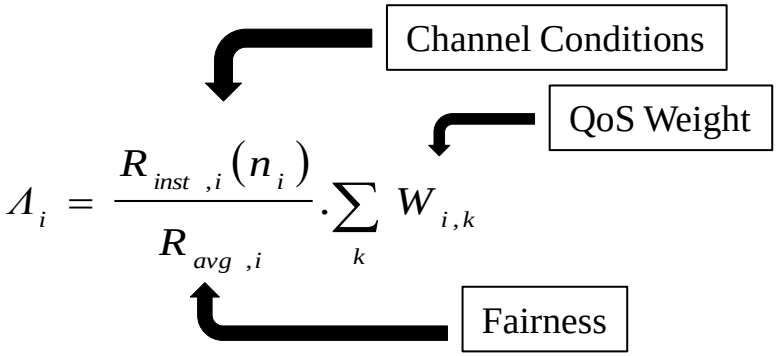

'weighted Proportional Fair' (wPF) metric algorithm
Sorting algorithm
QoS weight
channel conditions
fairness
QoS weight
rate budget
delay budget
delay threshold
Bubble sort

TDPS Metric (cont.)

- All active users in serving eNodeB get TDPS metric values
- TDPS metric values for user i
  - User QoS weight
  - User instantaneous achievable throughput
  - User Exponential Moving Average (EMA) throughput



where n_i is maximum number of PRBs user i can get (using PC), $R_{inst,i}$ is the total PRBs in system, $W_{i,k}$ is the QoS weight of bearer k of user i (dynamic weight)

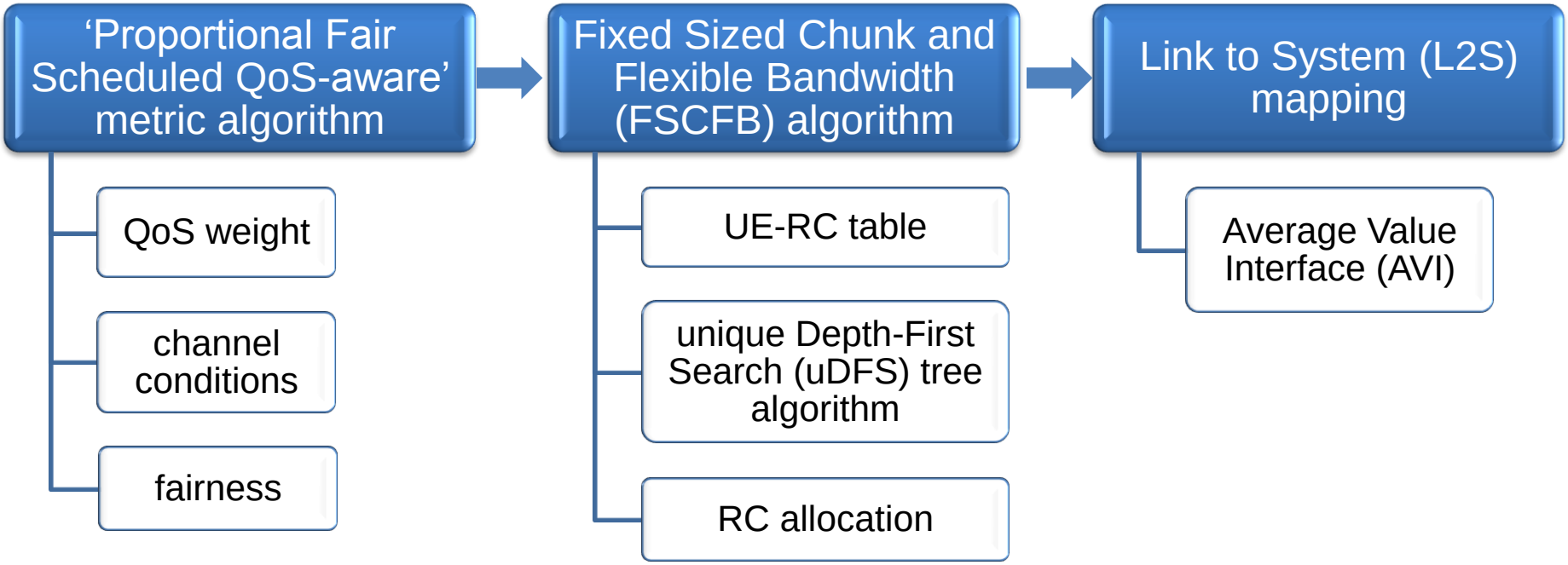
$$W_{i,k} = \frac{R_{min,k}}{R_{avg,i,k}} \cdot \frac{\tau_{i,k}}{\tau_{max,k}} \cdot \rho_k$$

where $R_{min,k}$ and $\tau_{max,k}$ are rate and delay budgets of bearer k, $R_{avg,i,k}$ is the average throughput of k, $\tau_{i,k}$ is the packet delay of k, ρ_k has value 10 if packet delay of k is above threshold, otherwise 1

FDPS Metric


'Proportional Fair Scheduled QoS-aware' metric algorithm
Fixed Sized Chunk and Flexible Bandwidth (FSCFB) algorithm
Link to System (L2S) mapping

FDPS Metric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unique Depth-First Search (uDFS) tree algorithm
RC allocation
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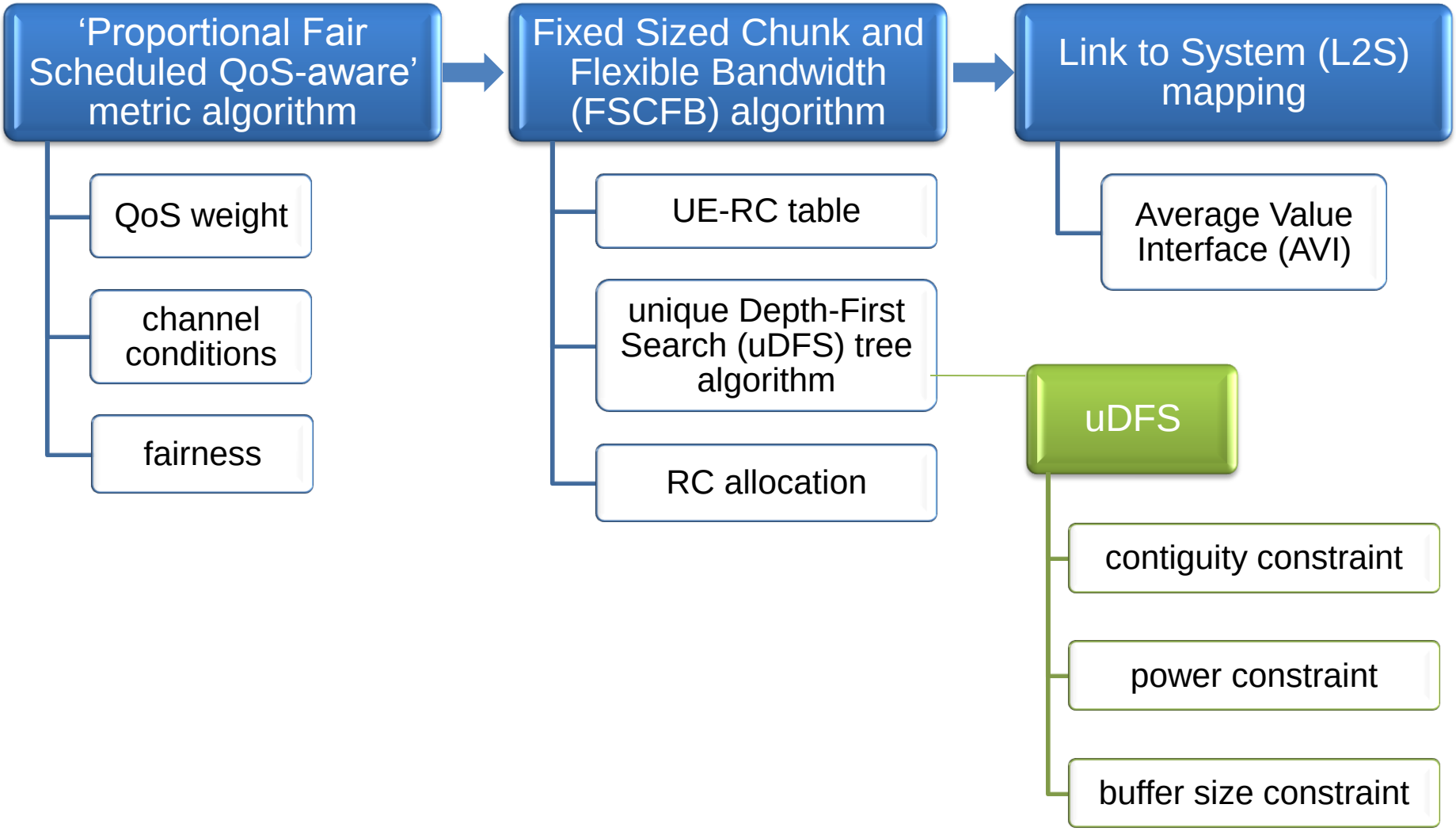
Average Value Interface (AVI)

FDPS Metric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RC allocation
uDFS
contiguity constraint
power constraint
buffer size constraint
Link to System (L2S) mapping
Average Value Interface (AVI)

FDPS Metric (cont.)

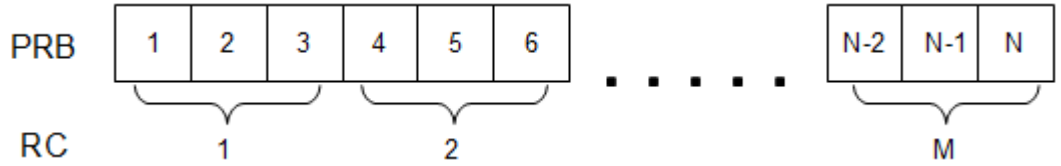
- All PRBs of all selected users get FDPS metric values
- FDPS metric value for PRB c of user i
  - User QoS weight
  - PRB instantaneous achievable throughput
  - User EMA throughput over TTIs when user entered FDPS

$$\gamma_i^c = \frac{r_i^c}{R_{sch,avg,i}} \cdot \sum_k W_{i,k}$$

where r_i^c is instantaneously achievable throughput of user i at PRB c and $R_{sch,avg,i}$ is average throughput of user i over the TTIs when it is scheduled by TDPS

Resource Allocation

- Divide the bandwidth into Resource Chunks (RCs)
  - RC is a group of contiguous PRBs
  - Algorithm complexity reduced



- Fixed Sized Chunk and Flexible Bandwidth (FSCFB)
  - Make UE-RC table of RC metric values
  - Determine all possible RC allocation combinations using ‘unique Depth-First Search’ (uDFS) tree algorithm with
    - Contiguity constraint
    - Power constraint
    - Buffer size constraint
  - Choose best combination
  - Allocate RCs accordingly

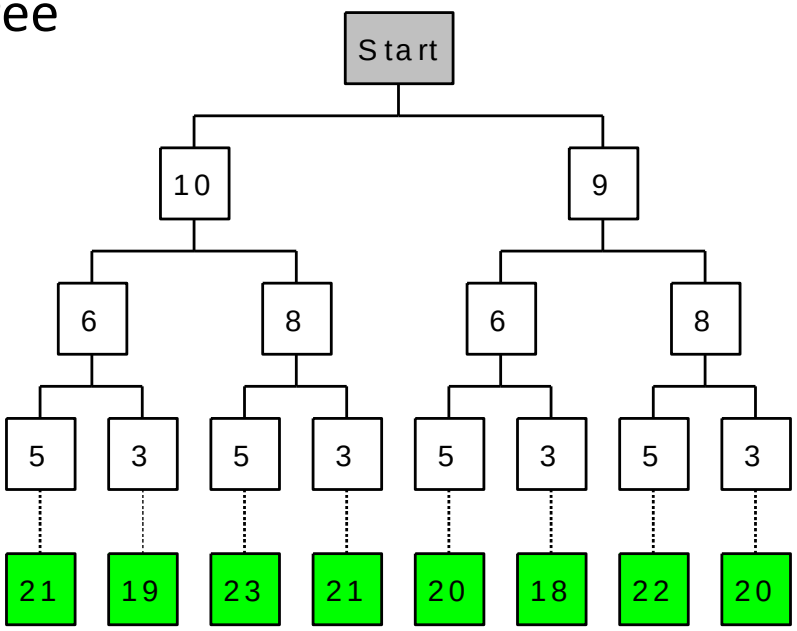
- Average Value Interface (AVI) for user SINR determination
  - Take average SINR of the PRBs allocated to a UE
  - Determine MCS for UEs according to average SINR
  - Determine TBS for UEs according to MCS

Resource Allocation (cont.)

- UE-RC table for 2 users and 3 RCs

	RC_0	RC_1	RC_2
UE_0	10	6	5
UE_1	9	8	3

- Corresponding tree

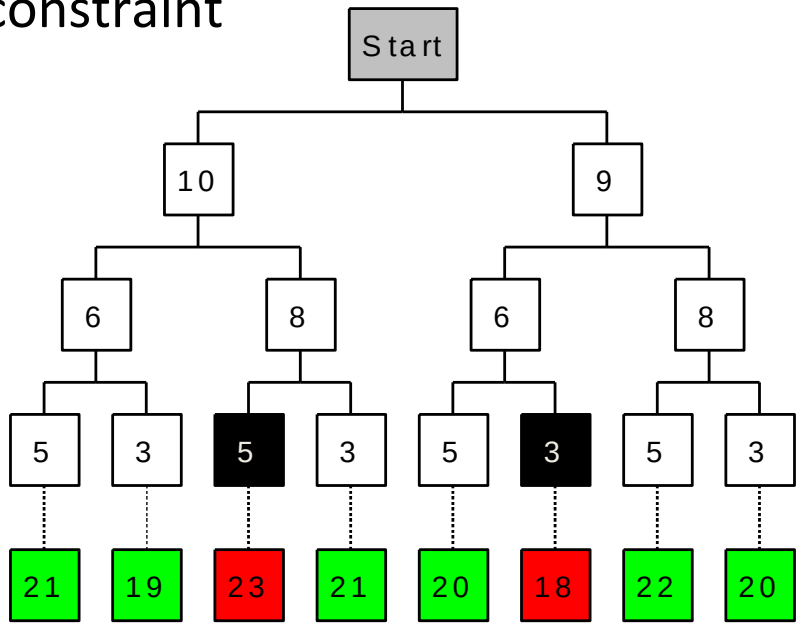


Resource Allocation (cont.)

- UE-RC table for 2 users and 3 RCs

	RC_0	RC_1	RC_2
UE_0	10	6	5
UE_1	9	8	3

- With contiguity constraint



Resource Allocation (cont.)

- UE-RC table for 2 users and 3 RCs

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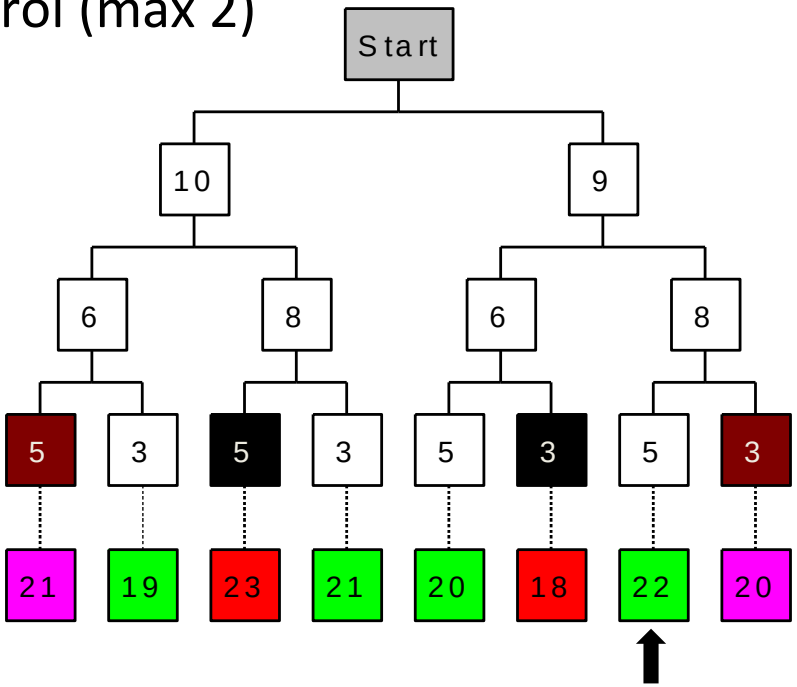
- With power control (max 2)



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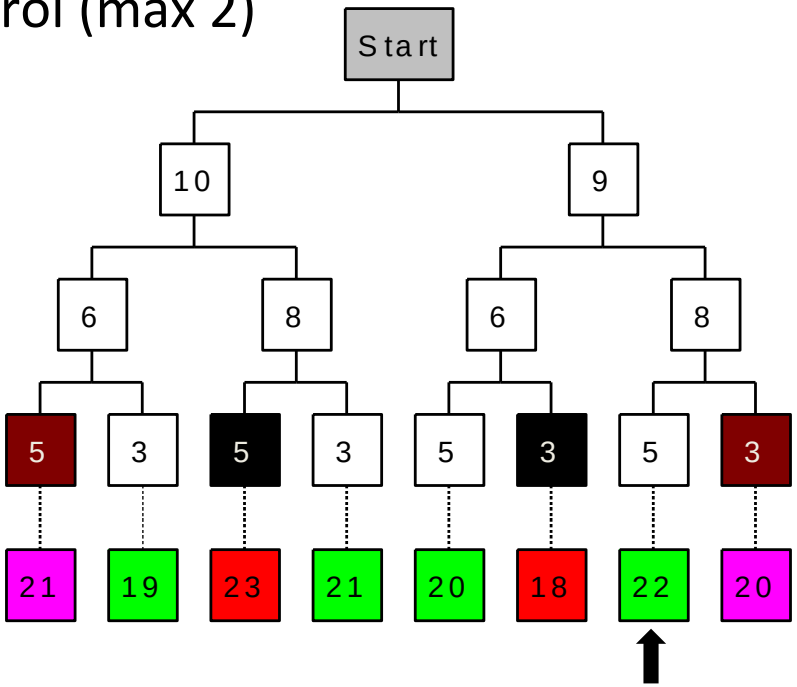
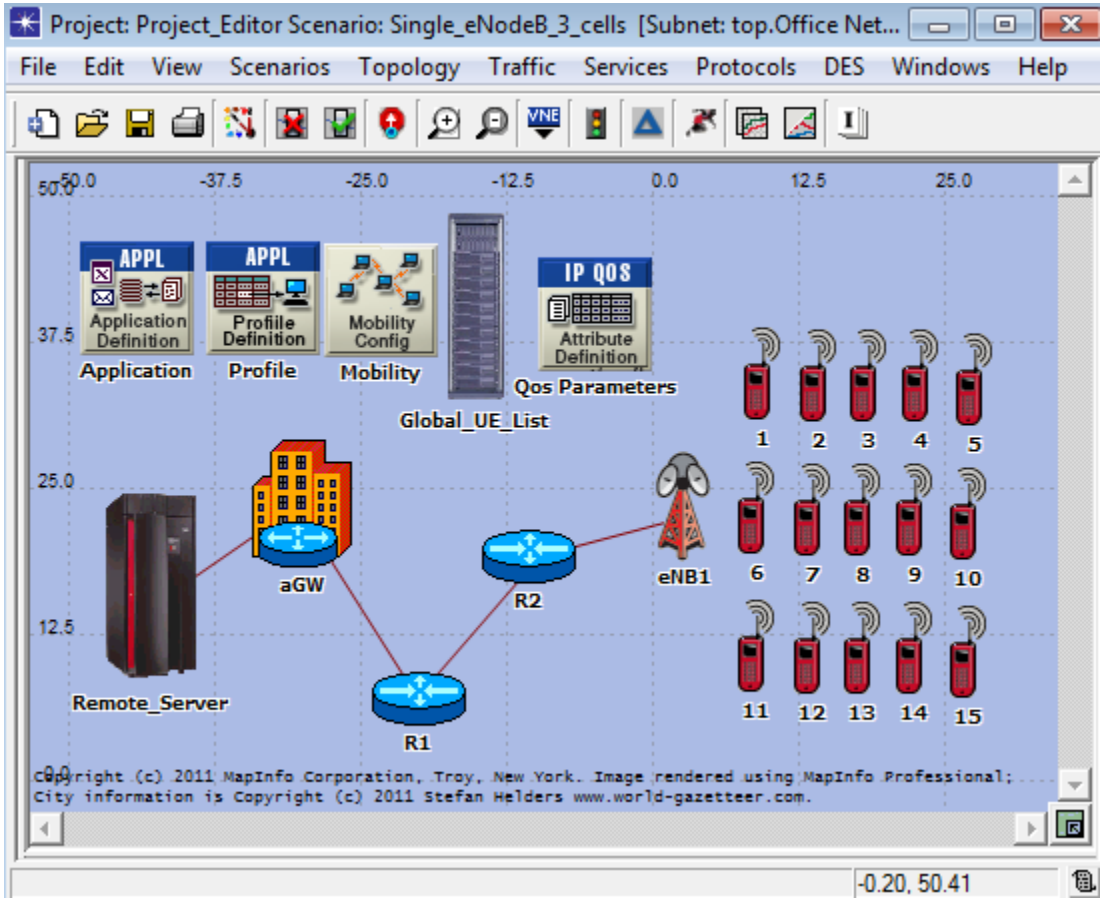


Multi-Bearer User Scheduling

- PRBs allocation to UE bearers
- All bearers sorted according to bearer QoS weight
- PRBs allocated to bearers according to priority
- Bearers scheduled

Simulation Analysis



Simulation Analysis (cont.)

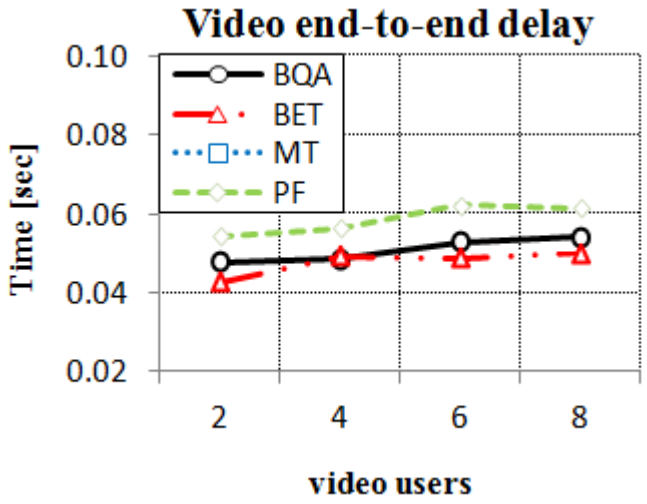
Parameter	Setting
Cell layout	1 eNodeB, 3 cells
System Bandwidth	5 MHz (~25 PRBs)
Frequency reuse factor	1
Cell radius	375m
User velocity	120kmph
Max UE power	23dBm
Path loss	$128.1+37.6\log_{10}(R)$, R in km
Slow fading	Log-normal shadowing, 8dB standard deviation, correlation 1
Fast fading	Jakes-like method
Mobility Model	Random Way Point (RWP)
UE buffer size	Infinite
Power Control	FPC, $\alpha = 0.6$, $P_0 = -58$dBm
Traffic environment	Loaded
Max FDPS user	5
RC size	5

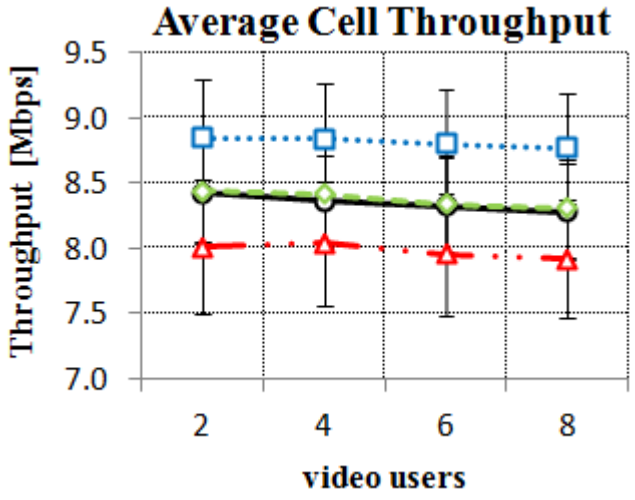
Simulation Analysis (cont.)

VoIP traffic model	
Silence/ talk spurt length	Exponential(3) sec
Encoder scheme	GSM EFR
Video traffic model	
Frame size	1200 bytes
Frame inter-arrival time	75ms
HTTP traffic model	
Page size	100Kbytes
Page inter-arrival time	12 sec
FTP traffic model	
File size	20Mbytes
File inter-request time	Uniform distribution, min 80s, max 100s

Single-Bearer Users

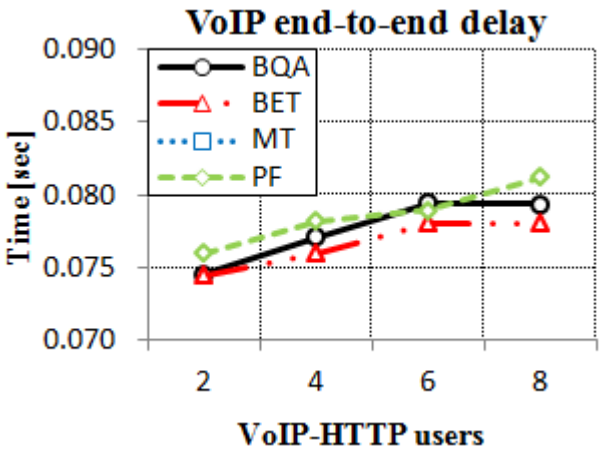
- Fixed 8 FTP users to keep the cell loaded
- Single-bearer video users added stepwise into the loaded cell

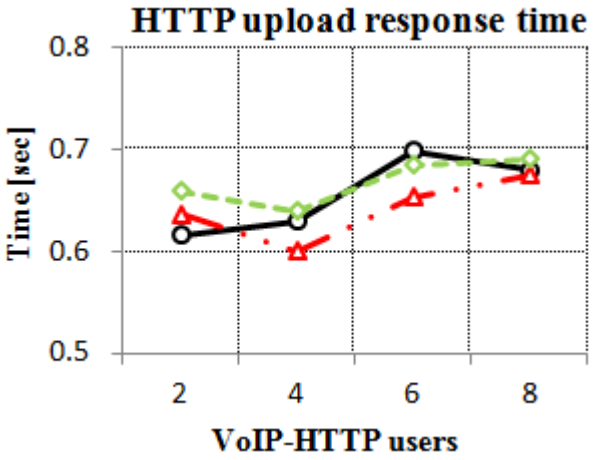


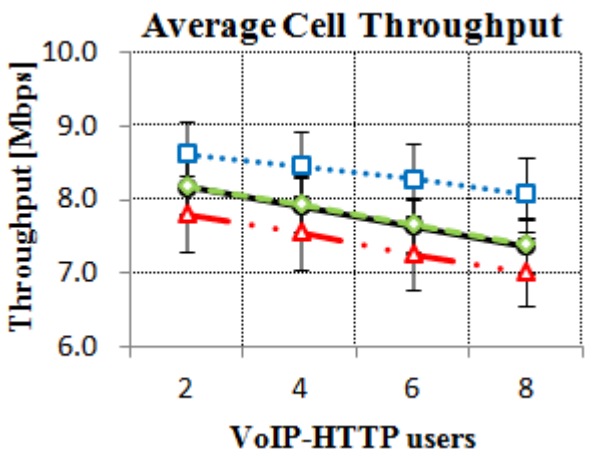


Double-Bearer Users

- Fixed 8 FTP users to keep the cell loaded
- Double-bearer VoIP-HTTP users added stepwise into the loaded cell

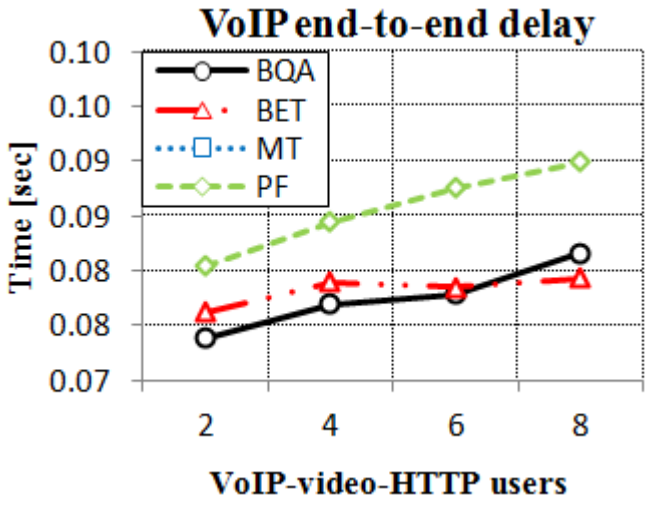


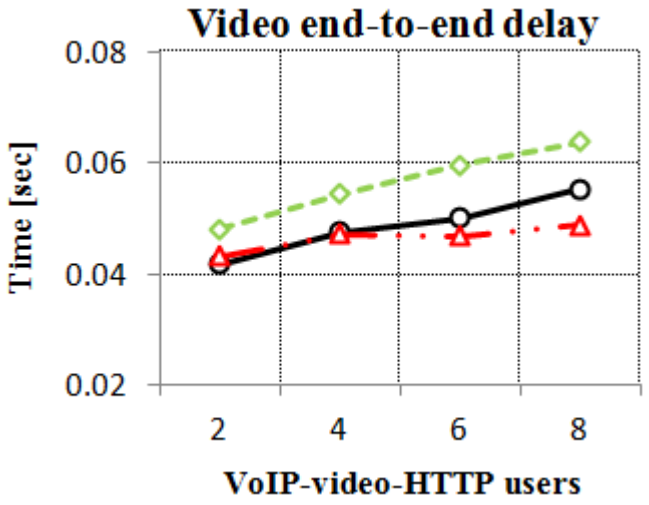




Triple-Bearer Users

- Fixed 8 FTP users to keep the cell loaded
- Triple-bearer VoIP-video-HTTP users added stepwise into the loaded cell





Triple-Bearer Users (cont.)

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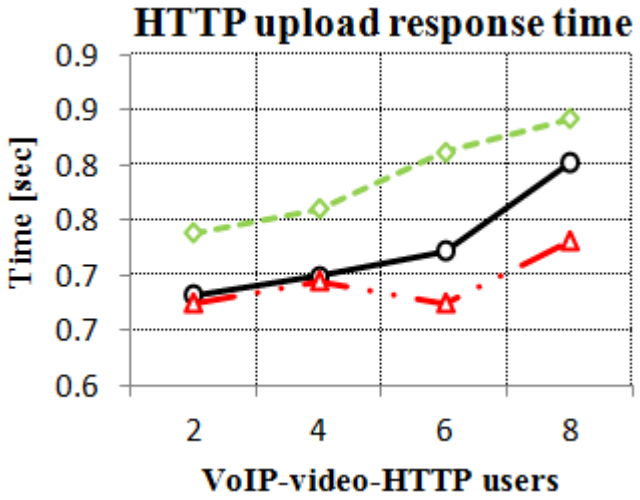

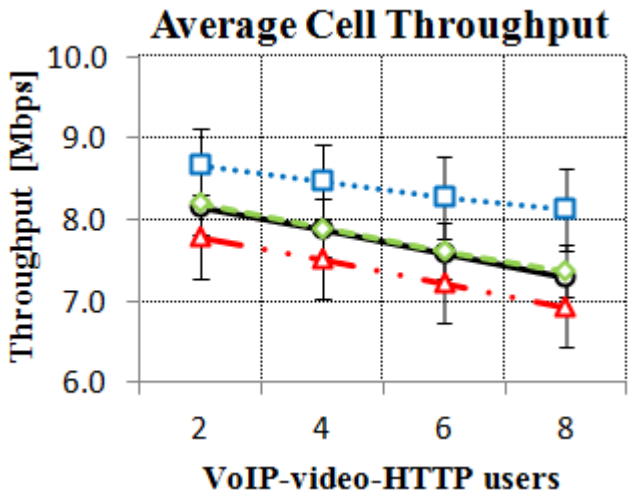

Conclusion and Outlook

- BQA scheduler evaluation
  - Delay sensitive traffic QoS guarantee
  - Comparison with contemporary schedulers
  - All schedulers utilize
    - Channel conditions
    - FSCFB (and uDFS) algorithm
    - Multi-bearer user scheduling
  - Dynamic QoS weight is the distinctive feature of BQA
- Future goals
  - Integrate HARQ functionality
  - Include Admission Control (AC) functionality

THANK YOU!

Questions???