Joint Time-Frequency Domain Proportional Fair Scheduler with HARQ for 3GPP LTE Systems

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Outline of Presentation

- 3GPP LTE Targets
- System and Channel Model
- Joint Time Frequency Scheduler
- Throughput and Fairness performance
- Conclusion

3GPP LTE Targets

Develop a framework for the evolution of the 3GPP radio-access technology towards a high-data-rate, low-latency and packet-optimized radio-access technology:

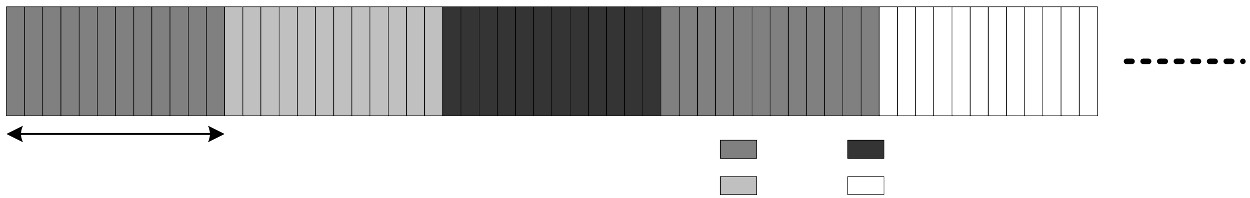
- Support of packet switched domain only (including VoIP).
- Significantly increased peak data rate: 100 Mbps (downlink) and 50 Mbps (uplink)
- 2 or 4 times capacity over Release 6 reference scenarios with HSDPA or HSUPA.
- Scalable bandwidth up to 20 MHz (lowest possible BW: 1.25 MHz).
- Radio Network user plane latency below 10 ms (RTT) with 5 MHz or higher spectrum allocation.
- Reduced complexity (of terminals)

Parameters for LTE OFDMA Downlink Transmission

Transmission BW		10 MHz
Sub-frame duration		1ms
Sub-carrier spacing		15kHz
Sampling frequency		15.36MHz (4x3.84MHz)
FFT size		1024
Number of occupied sub-carriers		601
Number of OFDM symbols per slot (Short/Long CP)		7/6
CP length (μs/samples)	Short	(4.69/72)x6 (5.21/80)x1
	Long	(16.67/256)

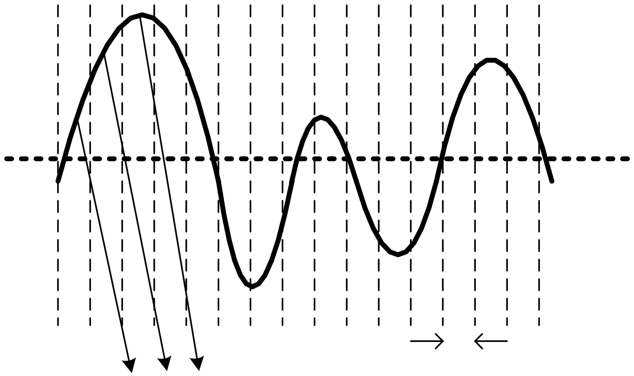
- Sub-carrier spacing is constant regardless of the transmission bandwidth
- Transmission bandwidth is varied by varying number of OFDM sub carriers to allow for operation in differently size spectrum

System and Channel Model



- To frequency multiplex users in the LTE system, the total bandwidth is divided into sub-channels, denoted as physical resource blocks (PRBs)
- A PRB is the minimum resolution for scheduling in the frequency domain. There are 50 PRBs in a 10MHz system, each consisting of a 12 neighbouring sub-carriers
- The sub-carrier bandwidth is 15kHz and the PRB bandwidth is 180kHz

System and Channel Model



- A single Channel quality indicator (CQI) (calculated from the average quality of the 12 sub-carriers) can be fed_back for each PRB as shown in figure
- It is assumed that the measured SNRs of each user are ideally fed back to be decoded by the BS without any error

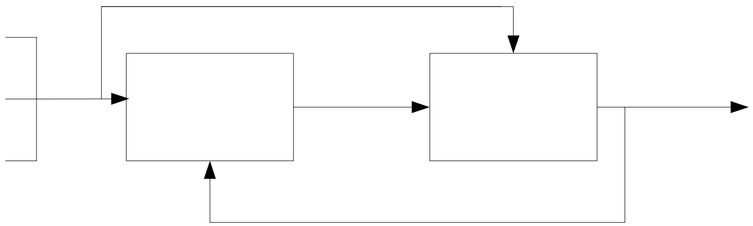
Default System Simulation Parameters and assumptions

Cell Layout	**Single Cell**
Radius of Cell	**500m (min 35 meter)**
BS Tx Power	**43dBm (20W)**
Max. No. of Retransmission	**4**
Carrier Frequency	**2GHz**
ARQ Scheme	**Chase Combining**
Propagation Model	**SCM – Urban Macro**
Shadowing	**SCM – Urban Macro**
Noise Power	**-104dBm (10MHz System Bandwidth)**
UE Noise Figure	**9dB**
Receiver Sensitivity	**-95dBm**
Packet Arrival	**Full Buffer**
Number of Time Simples (TTIs)	**20000 (10s)**
Average number of user per cell	**20**
MCS Update Rule	**Per frame (0.5ms) –Constant for ARQ retransmissions**
MCS Level	**QPSK ½ & ¾, 16QAM ½ & ¾ and 64QAM ½ & ¾**
Link Adaptation Target	**10% (PER10)**

Modulation and Coding Schemes used in the simulation

MCS	Modulation	Coding Rate
1	QPSK	1/2
2	QPSK	3/4
3	16 QAM	1/2
4	16 QAM	3/4
5	64 QAM	1/2
6	64 QAM	3/4

Joint Time-Frequency Scheduler



- In the joint time frequency scheduler, the first layer of scheduling will be implemented in time domain (TD) and followed by opportunistic scheduling and the second layer in the frequency domain (FD).
- The TD scheduler aims to select users with relatively good channel while maintaining fairness to all users.
- In combination with this, different FD schedulers with different aims are considered.

Time Domain Scheduler

- A Proportional Fair (PF) scheduler is considered
- Provide an attractive ability to trade-off between maximum average throughput and user fairness
- Allocate resource in any given scheduling interval to a user whose channel condition is near its peak.
- Allocate approximately the same number of resources to all users (averaged over a period of time)

$$P_k(t) = \frac{R_k(t)}{T_k(t)} \quad \textit{at any time slot } t$$

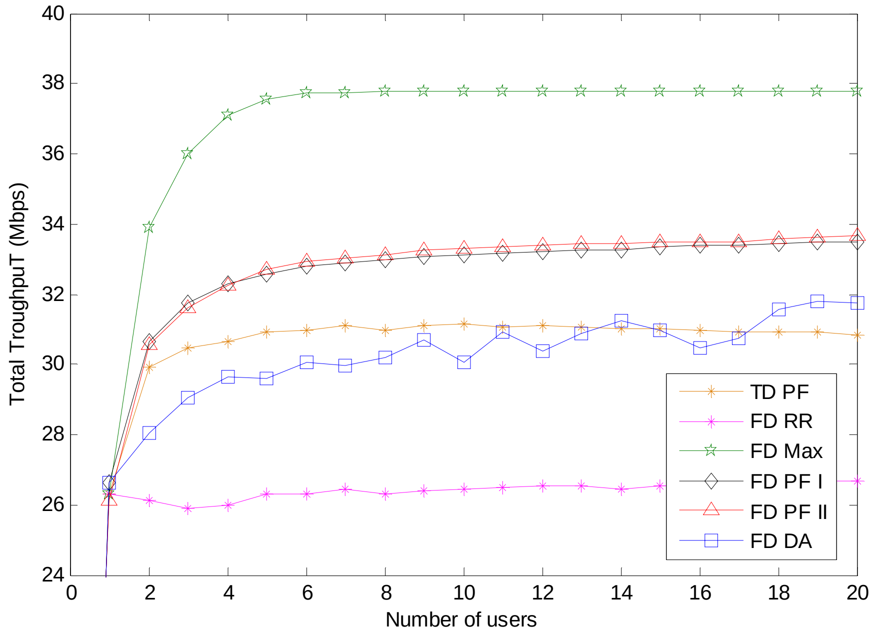
Frequency Domain Packet Scheduler

- Explore the potential of joint diversity in both frequency domain and time domain to achieve efficiency and facilitate QoS/fairness
- In LTE system, the total bandwidth is divided into smaller chunks, denoted as physical resource blocks (PRBs)
- Smaller frequency resolution gives a larger degree of freedom but overhead and complexity is an issue
- PRB based adaptation and scheduling will reduce signalling overhead and complexity
- Joint diversity gives more freedom to achieve joint goals

Frequency Domain Packet Scheduler

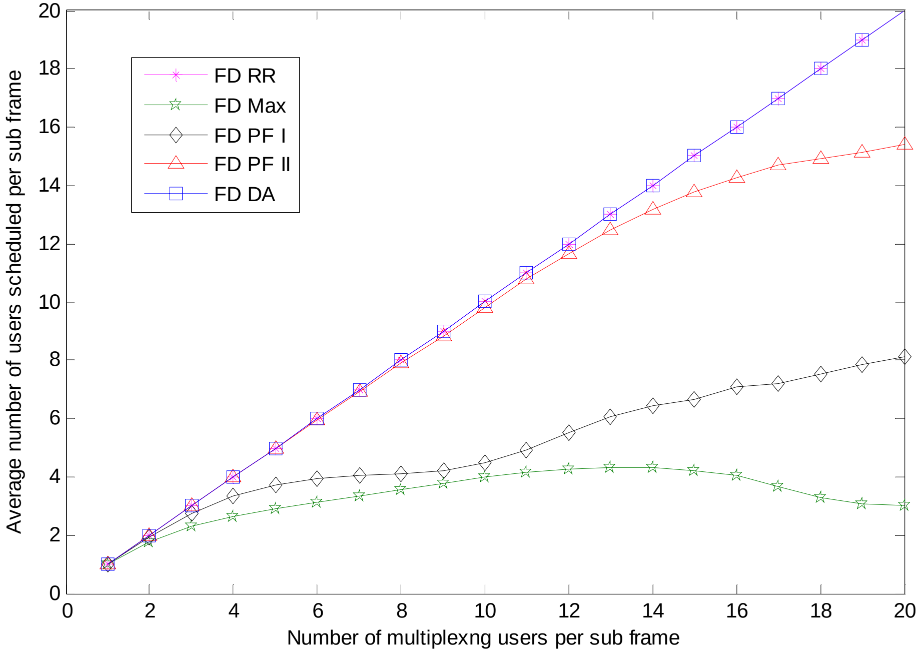
- **No Frequency Domain Scheduling (TD-PF)**
- **Frequency-Domain Round Robin (FD-RR)**
- **Frequency-Domain Max C/I (FD-MAX)**
- **Frequency-Domain Proportional Fair (FD-PF)**
  - Two FD-PF strategies are considered :
    - Strategy I: The average throughput T*k*(t) is updated for each new time interval (after all PRBs are allocated)
    - Strategy II: The average throughput Tk(t) is updated after each PRB is allocated.
- **Frequency domain Dynamic Allocation (FD-DA)**
  - Loop through all the users and choose the highest channel gain among the available resources
  - Subsequence loops start with least channel gain in order to achieve equal channel gain among all the users

Throughput performance with increasing number of users in a cell



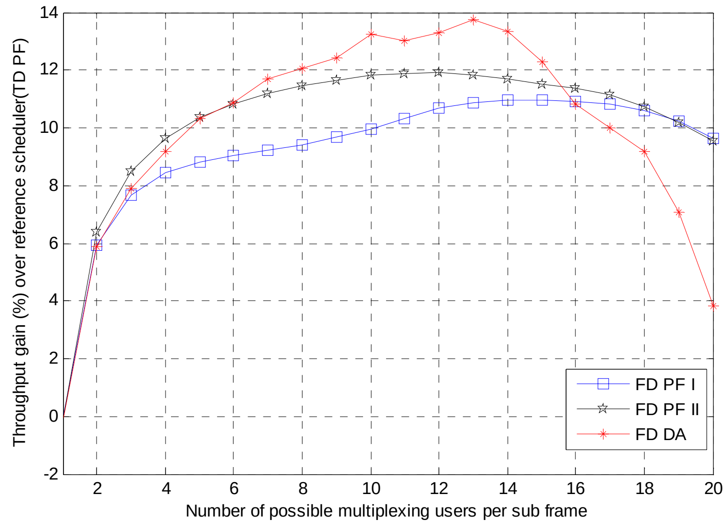
- FD-MAX and FD-RR schedulers mainly serve as reference schedulers
- To quantify the performance gain of additional opportunistic scheduling in frequency domain, the TD PF scheduler is also considered

Number of multiplexing users vs. scheduled users



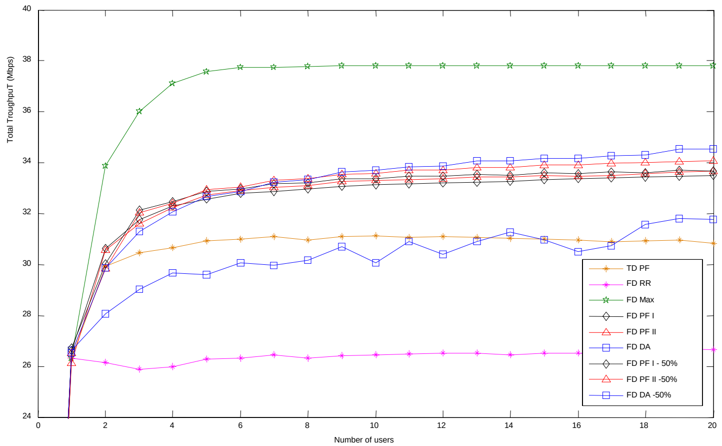
- Not all the users are actually scheduled per time slot due to the nature of the schedulers

Performance gain of increasing number of possible multiplexing users in a sub frame



- TD-PF as reference
- Maximum at 50 -70% of users

Throughput performance with 50% users selected of all multiplexing users

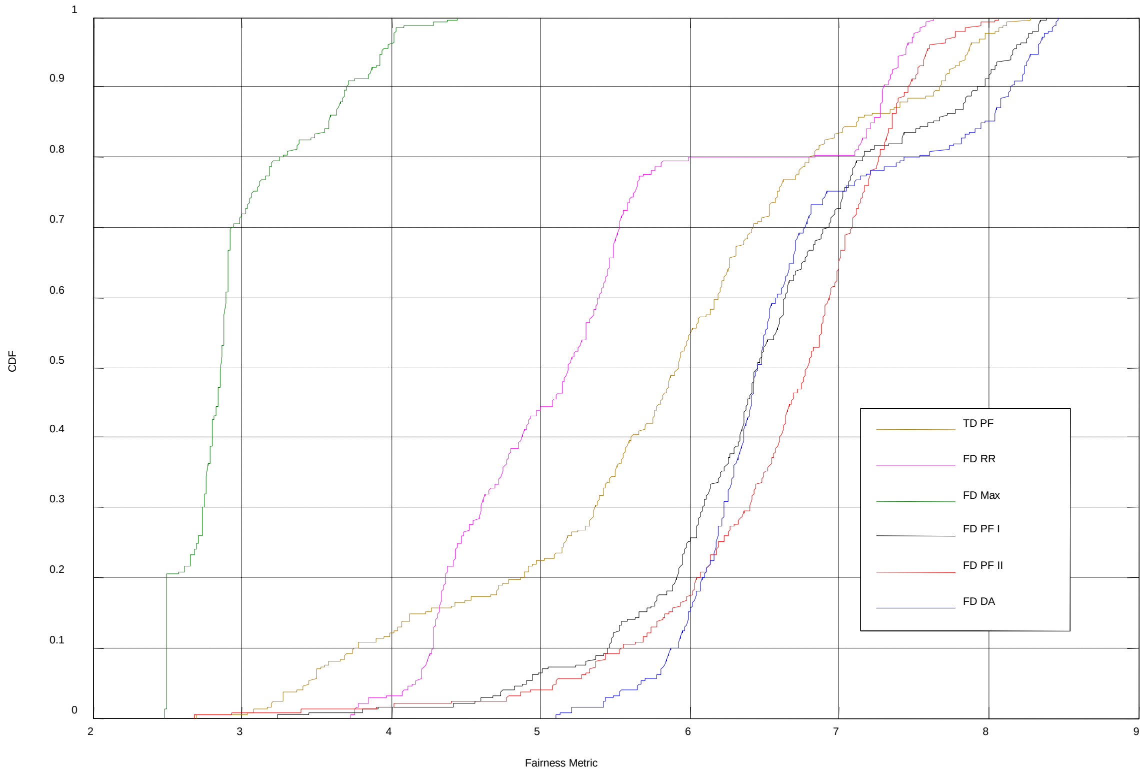


- It can be seen that FD-DA outperforms all other schemes except TD-MAX
- It can also be seen that the FD-PF strategies are much less sensitive than FD-DA to the number of multiplexing users.

Fairness Performance

- Throughput gain is often achieved through some kind of compromise in fairness and vice versa
- Proportionally fair scheduler should maximize the sum of logarithmic average user rates
- Plot CDF of the system over different instances in the simulation

$$Fairness\_Metric(i) = \left(\prod_{n=1}^{k} R_{inst}(i) \right)^{\frac{1}{k}}$$



- Both FD-PF strategies achieve better fairness than the TD-PF scheduler, with FD-PF-II superior due to its more frequent update of the average throughput T_k
- FD-DA maintains an element of fairness by allocating equal resources, also performs well, achieving fairness better than TD-PF and FD-PF-I and similar to FD-PF-II.

Conclusion

- Evaluate the potential gain achievable joint time-frequency scheduling
- Joint time-frequency scheduling achieves significant improvements
- Approximately 50-70% of all multiplexing users should be selected to transmit to gain the best exploitation of diversity
- Proportional fair scheduling in both time and frequency domains achieve good performance in terms of both throughput and fairness
- A combination of TD proportional fair and FD dynamic allocation achieves similar fairness and superior throughput

Thank you