Adaptive Radio Resource Management in 4G UMTS and LTE Communications

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Outline

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  - Phase 1: the Loads of UMTS and LTE Determination Phase (LDP)
  - Phase 2: the connection Admission control and Classification Phase (ACP)
  - Phase 3: the Dynamic resource Allocations of UMTS and LTE Phase (DAP)
- Numerical results
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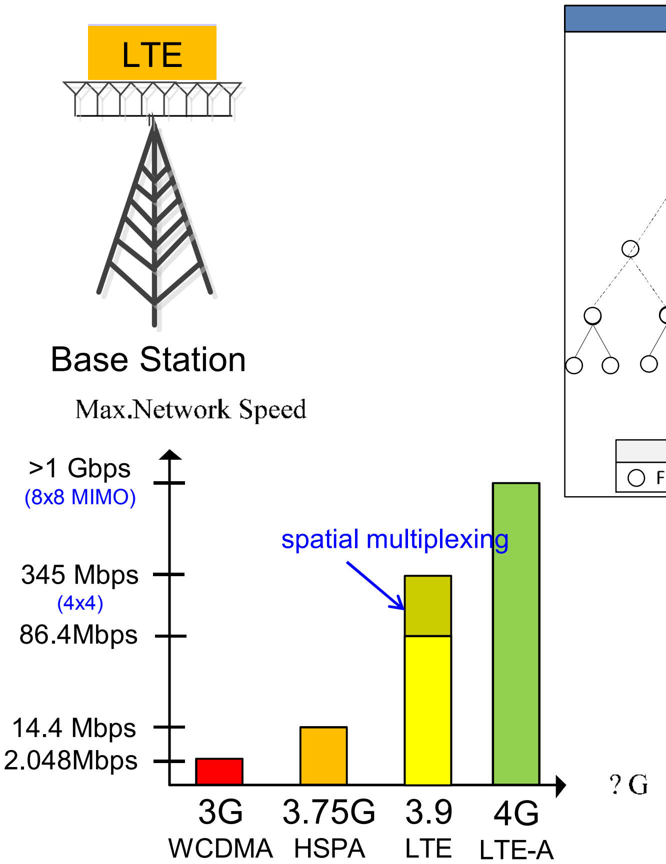
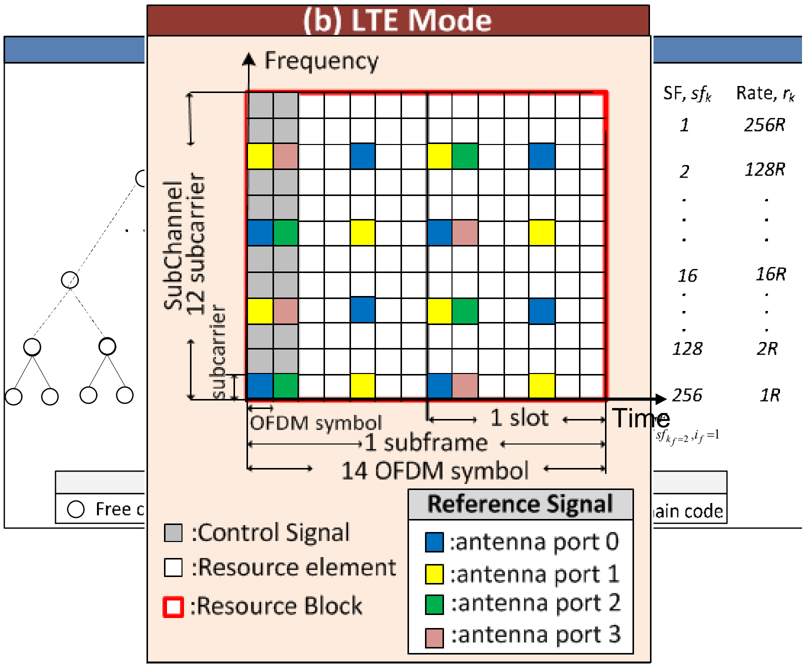
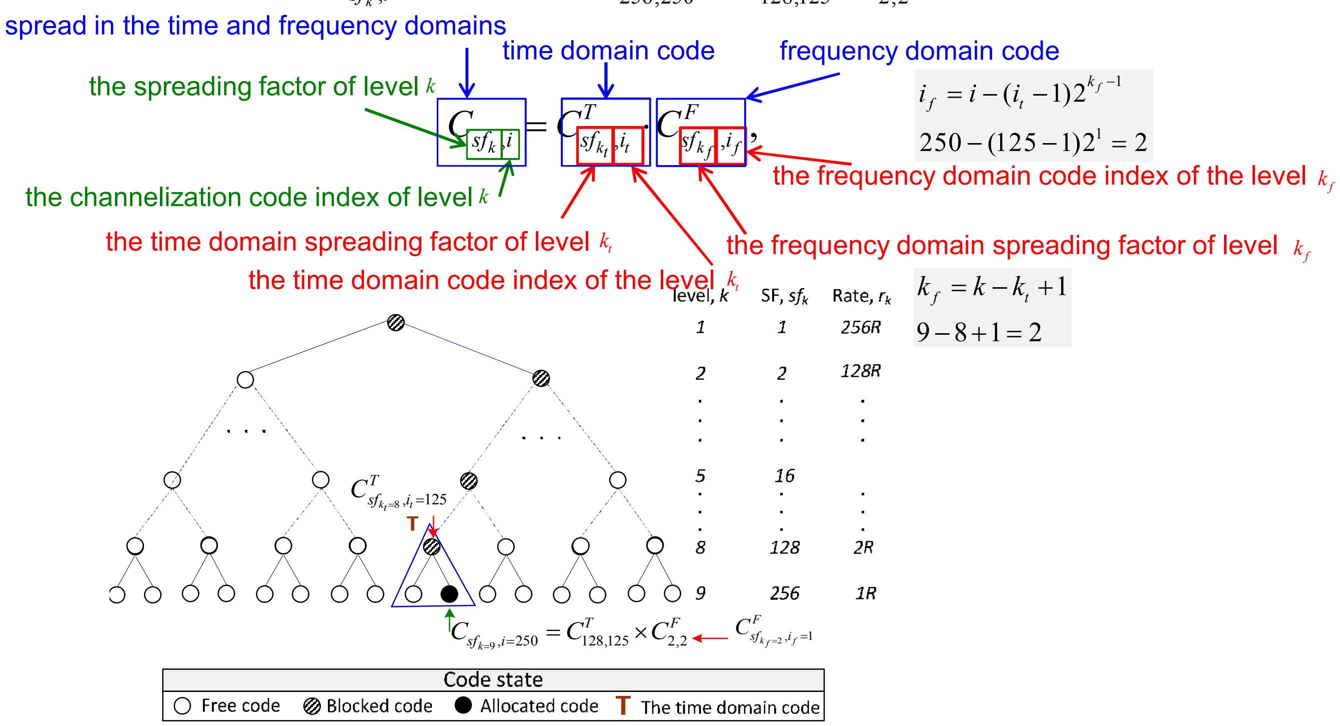
Overview



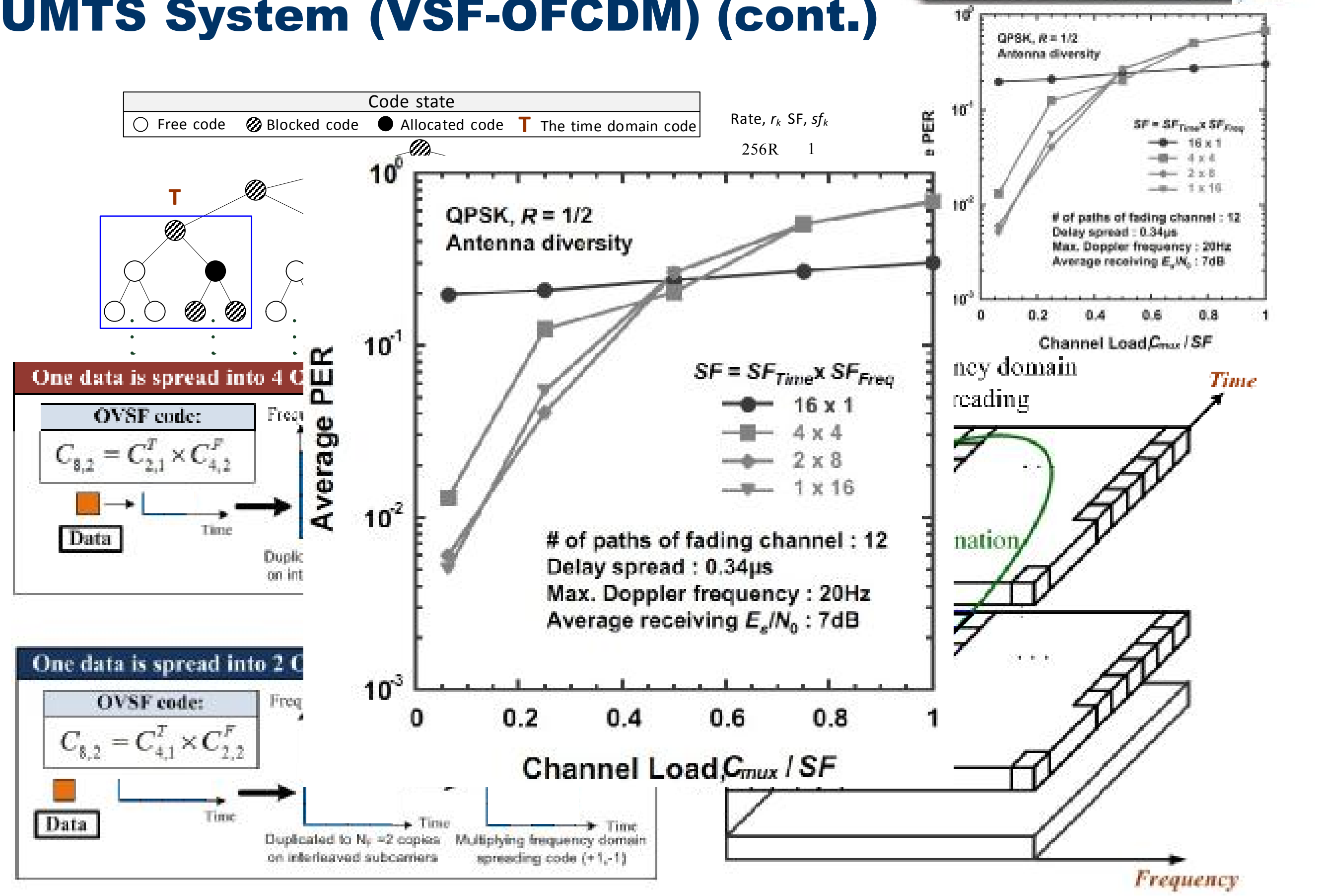


UMTS System (VSF-OFCDM)

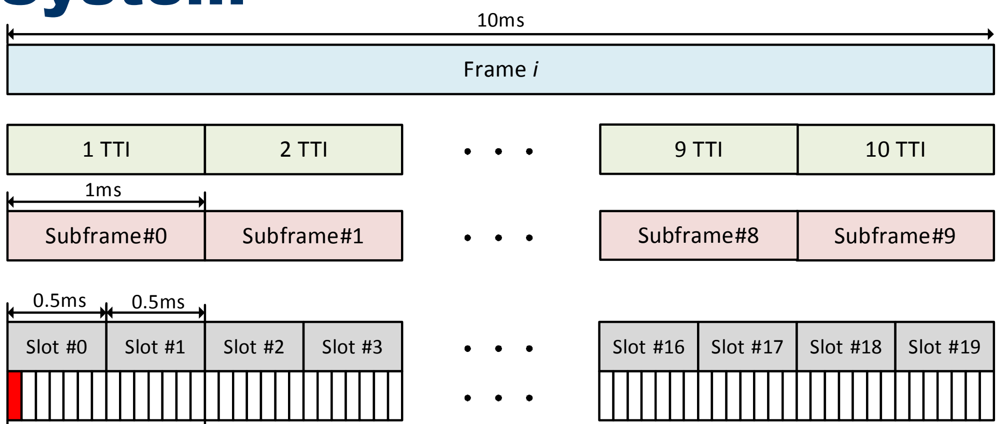
- the OVSF code tree has height K. A channelization code of level is denoted as $C_{sf_k,i}$ $\qquad C_{256,250} = C^T_{128,125} \cdot C^F_{2,2}$

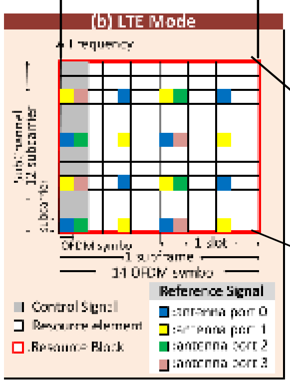


UMTS System (VSF-OFCDM) (cont.)

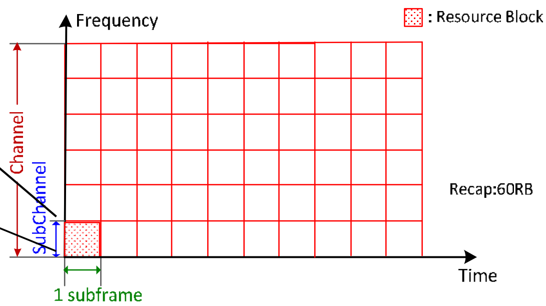


LTE System





Channel Bandwidth (MHz)	1.4	3	5	10	15	20
Number of RBs within a subframe time	6	15	25	50	75	100



LTE System (cont.)

Modulation		Antenna	Bit/symbol	1 RB (Kbps)
QPSK	½	Single antenna	1	144
16QAM	½	Single antenna	2	288
16QAM	¾	Single antenna	3	432
64QAM	1	Single antenna	6	864
64QAM	1	2 x 2 MIMO	12	1728
64QAM	1	4 x 4 MIMO	24	3456

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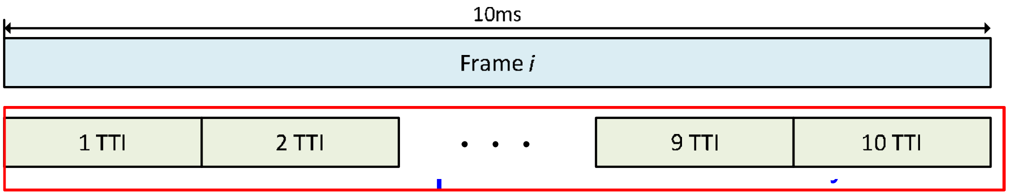
Total of dat



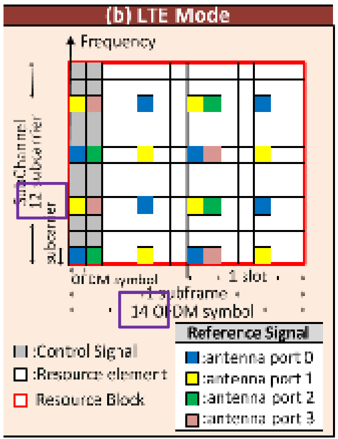
number of subcarriers

Channel Bandwidth (MHz)	1.4	3	5	10	15	20
Number of RBs within a subframe time	6	15	25	50	75	100

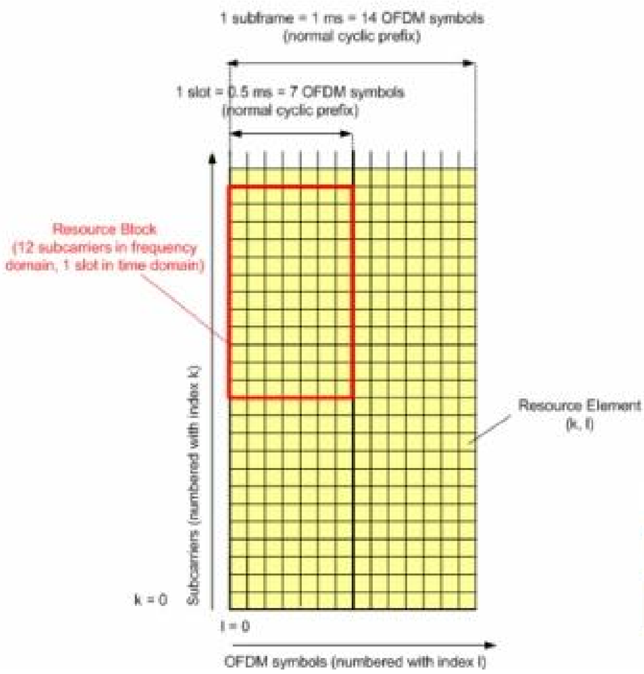
example

R_{DL}

$$1RB = 1(RBs)\cdot 12(subcarriers)\cdot 12(symbols)$$
$$\cdot 24(bits/symbol)\cdot 10(TTIs)\cdot 100$$
$$= 3456Kbps,$$



Resource Block (Downlink)

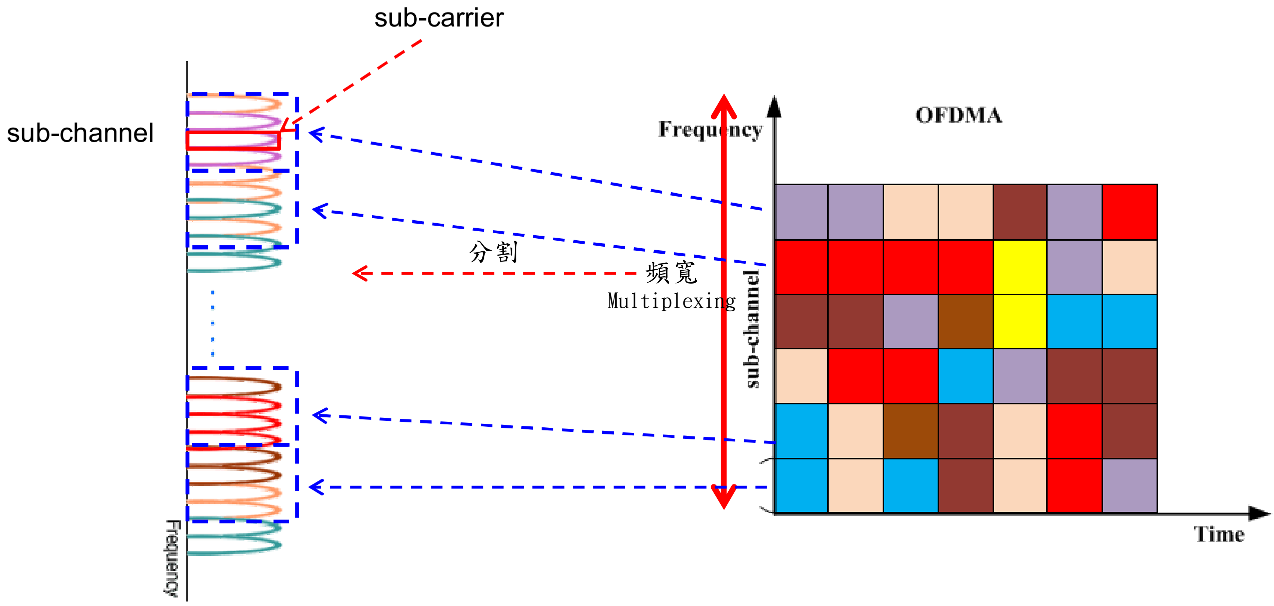


- Frequency(以頻率的角度來說):
  - OFDM-最小單位為sub-carrier
  - OFDMA-是以sub-channel為一個群組單位，1個sub-channel有12個sub-carrier
  - 在OFDM和OFDMA的每個sub-carrier都為orthogonal，每個carrier的Guard很接近但不相連。
  - 隨著每個channel bandwidth不同，channel所包含的sub-channel也不同

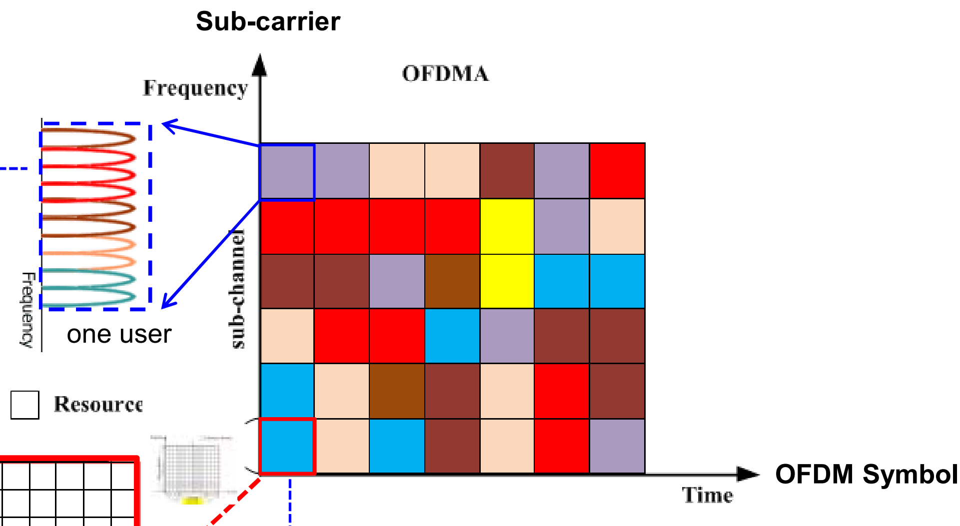
Table 3 Number of resource blocks for different LTE bandwidths (FDD and TDD) [Ref. 4]

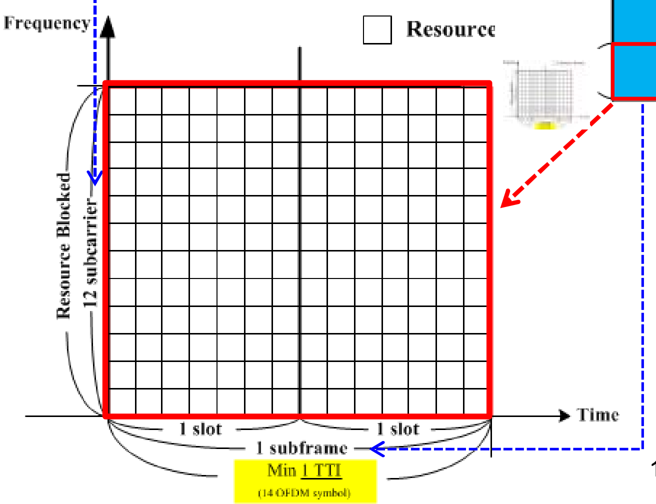
Channel bandwidth [MHz]	1.4	3	5	10	15	20
Number of resource blocks	6	15	25	50	75	100

OFDMA



OFDMA





- 一個sub-channel只能分配一個user，user可有多個sub-channel。
- 在一個sub-frame時間要傳一個Resource Block (12個sub-carrier)，一個Resource Block代表一個user。
- OFDMA在一個sub-frame時間需傳輸全部的sub-channel，也就是說一個sub-frame時間下傳輸多個user的Resource Block。

OFDMA-MIMO

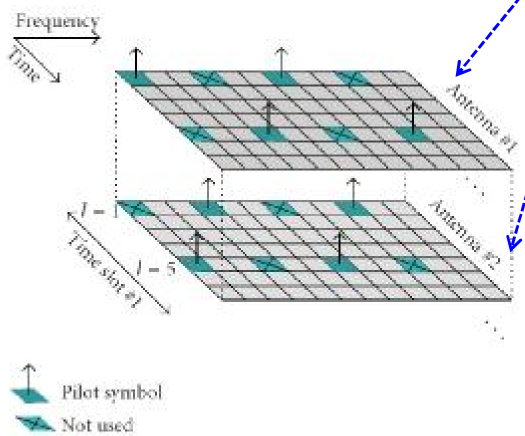
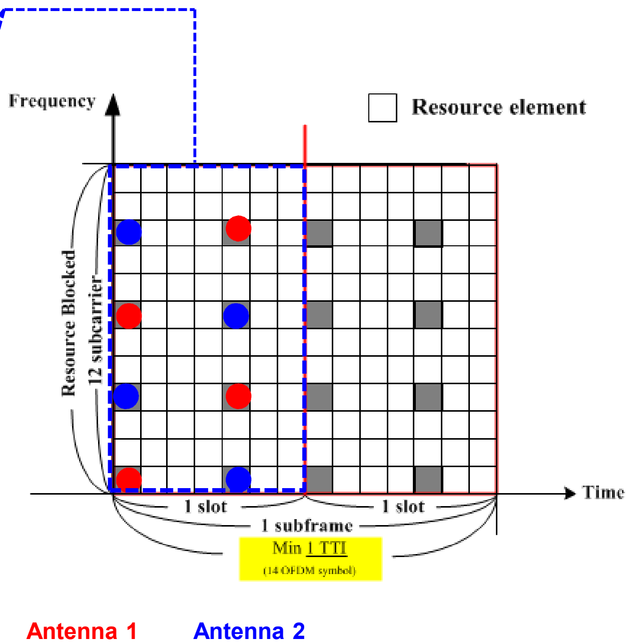
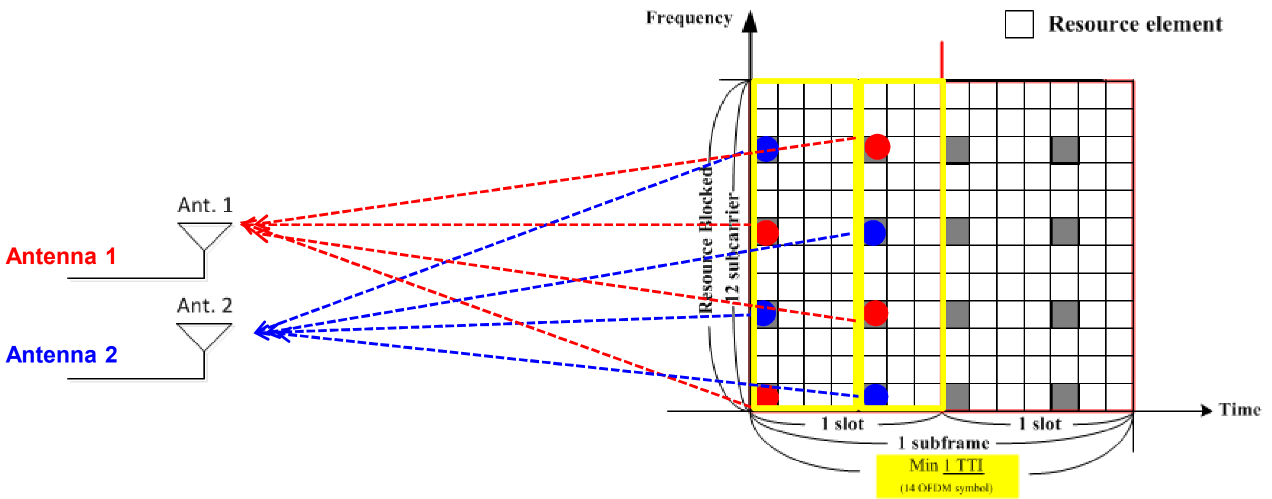


FIGURE 6: Example of 2D pilot arrangement with 2-antenna transmission.



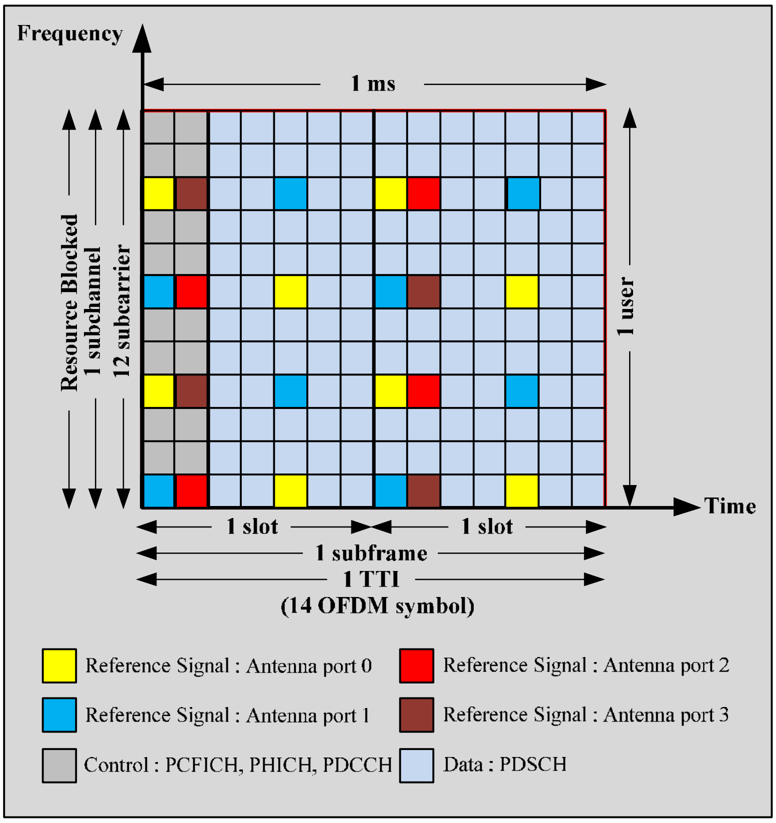
OFDMA-MIMO

- 一根天線負責多個sub-carrier、多個user (不同的RB)。
- 一個sub-carrier可以有多個天線的Reference Signal (RS)，也就是說在同一個sub-carrier可以在一個sub-frame的時間下，透過不同的時間點傳送不同的天線RS



Resource Block (Downlink)

- 4 antenna case



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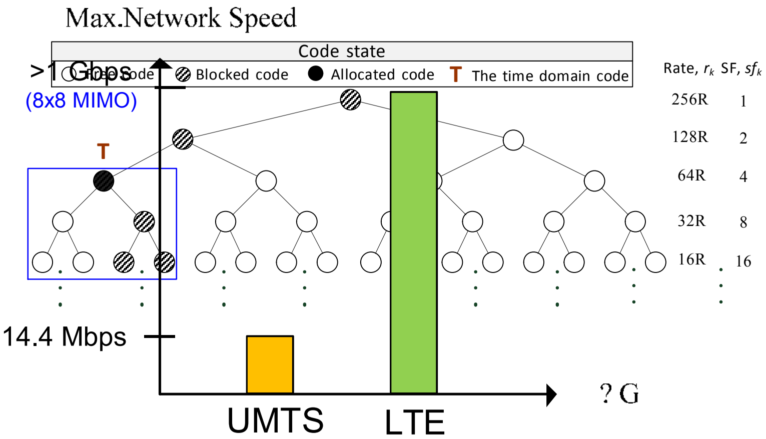
Issue

- UMTS system
  - high packet loss rate.
  - high bandwidth waste rate,
  - not consider user area
- LTE system
  - Suffers from unbalanced loads and unfair bandwidth utilization.

Single Code
Request : 33R
Waste rate : 31R



Related Works

- The code allocation algorithms of the VSF-OFCDM scheme can be classified into three types:
  - the allocations of 2D-based single code [13], [14]
    - 2D-single
  - single code [15]-[21]
    - CF
    - LM

  Disadvantage

  they suffer from wasting the bandwidth when the request data rate does not meet the data rate of a channelization code of the VSF-OFCDM code .

  - multicode [22]-[29], [38]
    - 3GPP_MS
    - AVCS

  Disadvantage

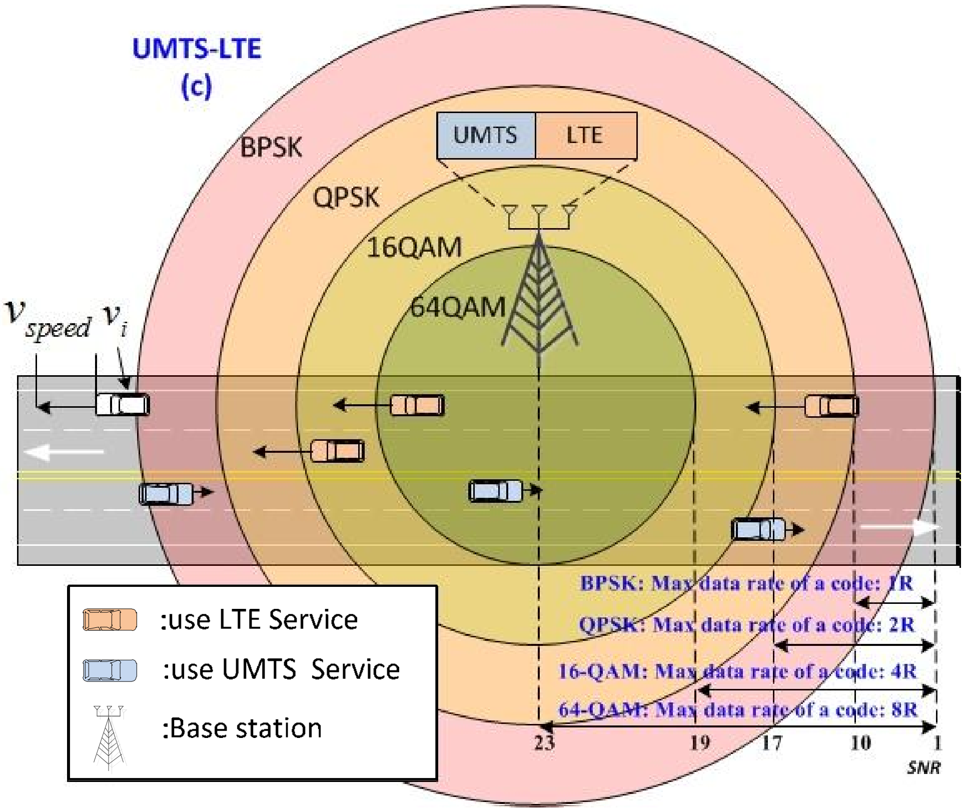
  the most important process in the multicode allocation is to partition the required data rate of a new incoming connection according to the residual radio resources

  - **Disadvantage**
    - not consider user locale.

Motivations & Goals

- **Motivations**
  - This paper proposes an Adaptive Radio-resource Allocation (ARA)
    - the LTE and UMTS interfaces according to the conditions of a mobile node
- **Goals**
  - An efficient radio resource management required
    - maximize reward
    - balance loads
    - minimize bandwidth waste rate

Network model



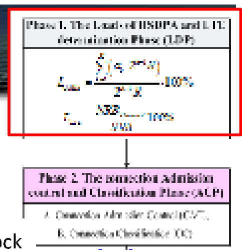
ARA Approach

- This paper proposes an Adaptive Radio-resource Allocation (**ARA**) approach for managing radio resource in the next generation high-speed cellular communication. The ARA approach consists of three main phases:
  - Phase 1: the Loads of UMTS and LTE Determination Phase (LDP)
  - Phase 2: the connection Admission control and Classification Phase (ACP)

    Goal: maximize the interface reward and to minimize the interface overhead
  - Phase 3: the Dynamic resource Allocations of UMTS and LTE Phase (DAP)

    Goal: guaranteeing the QoS and achieving BS's loads balancing

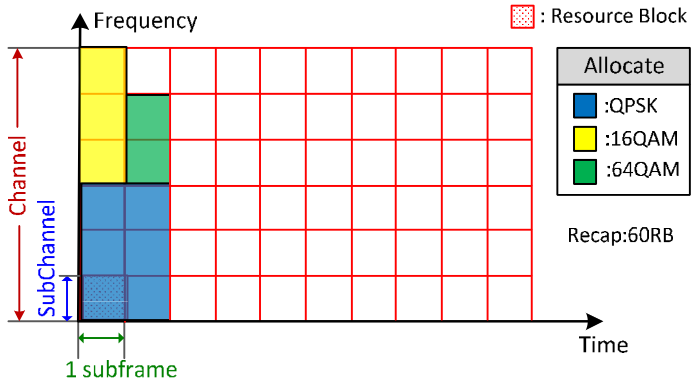
Phase 1: the Loads of UMTS and LTE Determination Phase (LDP)



- L_{UMTS} is compu… and the total capacity s… …tal of …nelization codes

system loa…

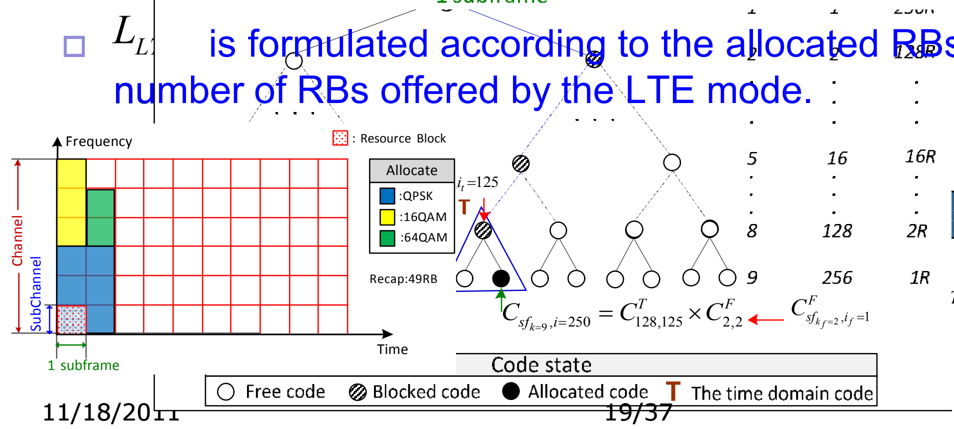
$\cdot 100\% = 0.390625\%,$



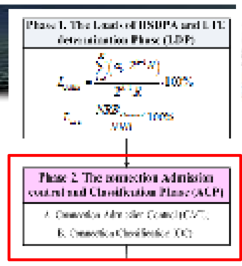
- L_{LTE} is formulated according to the allocated RBs and the total number of RBs offered by the LTE mode.

…mple

$L_{LTE} = \frac{11}{60}\cdot 100\% = 18.33\%,$



Phase 2: The connection Admission control and Classification Phase (ACP)



- Connection Admission Control (CAC)
  - capacity-based
- Connection Classification (CC)
  - 1) the interface loads of the eNodeB (L_{UMTS} and L_{LTE}).
  - 2) the reward (r_m) of the required traffic class (m),
  - 3) the velocity (v_i) of mobile node i .

Phase 2: The connection Admission control and Classification Phase (ACP) (cont.)

- **First**, if both loads, L_{UMTS} and L_{LTE}, of the eNodeB are all below or all above their individual thresholds,

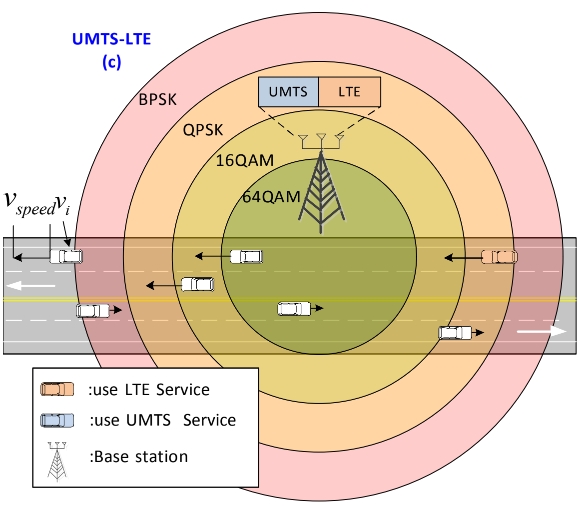
$$L_{LTE} < L_{LTE}^{S} \qquad L_{UMTS} < L_{UMTS}^{S}$$

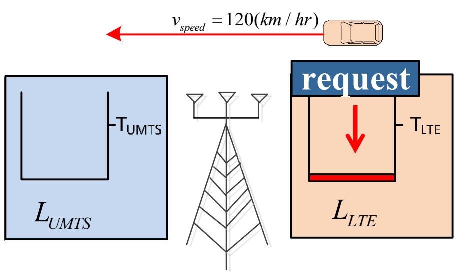
$$L_{LTE} \geq L_{LTE}^{S} \qquad L_{UMTS} \geq L_{UMTS}^{S}$$

- the eNodeB determines the communication interface by using the factors of mobile node velocity (v_i) and the carrying reward (r_m).

Phase 2: The connection Admission control and Classification Phase (ACP) (cont.)

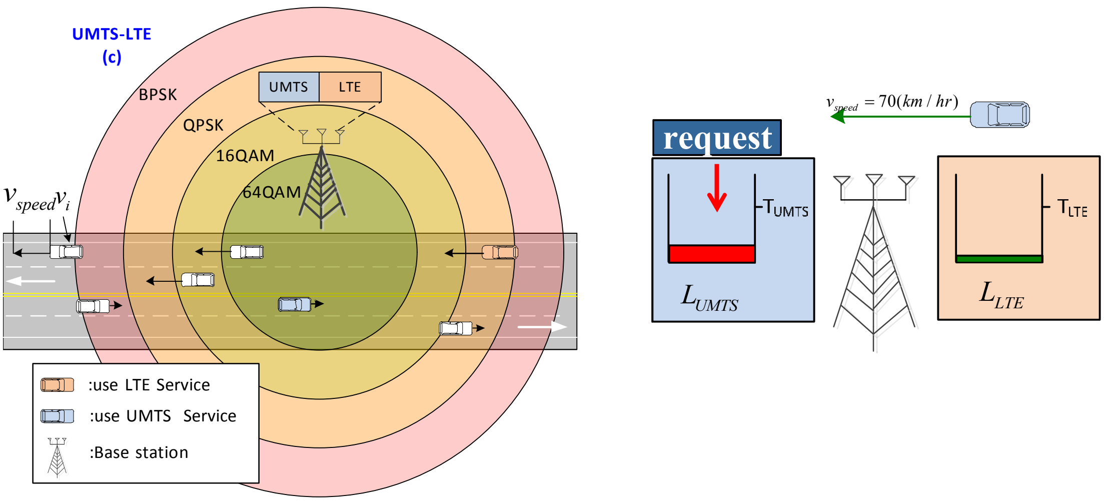
- ACP allocates LTE to a new connection if the carrying reward of using LTE is larger than that of using UMTS (i.e., $r_m^{LTE} > r_m^{UMTS}$), or the mobile node is with a high speed (e.g., $v_i \geq v^S$). Otherwise, ACP allocates UMTS to the new connection.





Phase 2: The connection Admission control and Classification Phase (ACP) (cont.)

- ACP allocates LTE to a new connection if the carrying reward of using LTE is larger than that of using UMTS (i.e., $r_m^{LTE} > r_m^{UMTS}$), or the mobile node is with a high speed (e.g., $v_i \geq v^S$). Otherwise, ACP allocates UMTS to the new connection.



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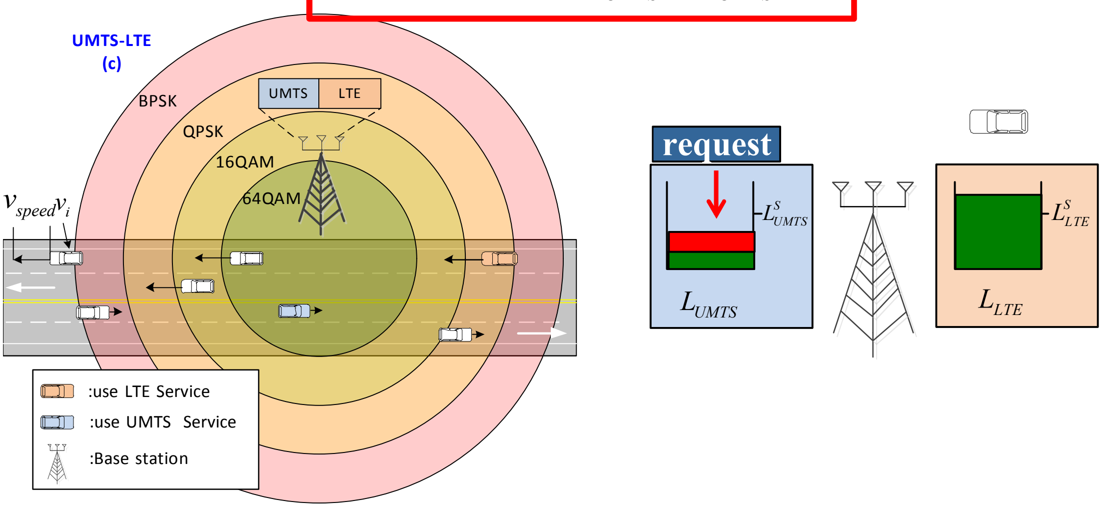
Phase 2: The connection Admission control and Classification Phase (ACP) (cont.)

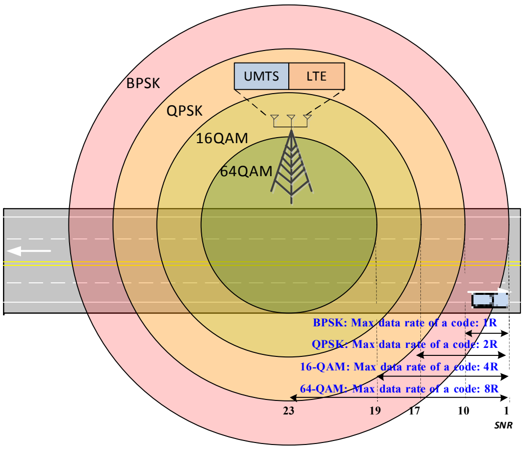
- **Second**, if only one interface exceeds its threshold, ACP allocates another interface to the new incoming connection.

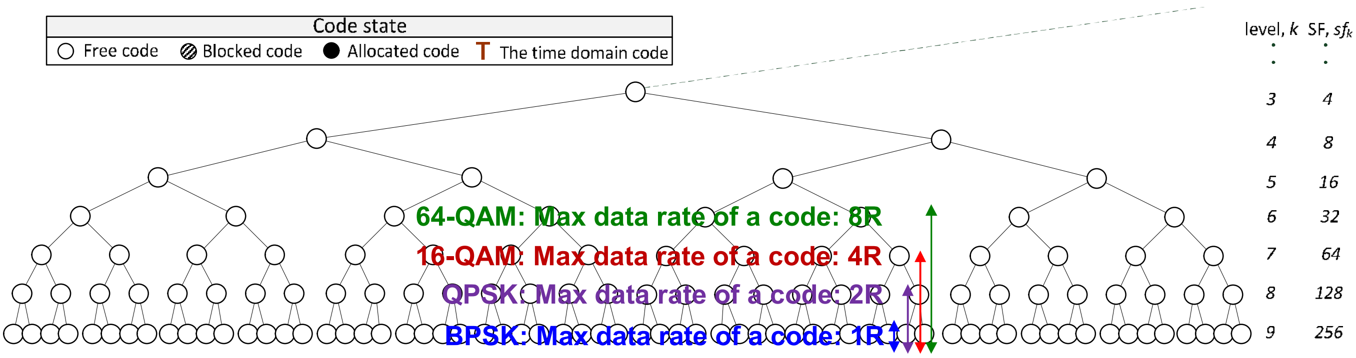
$$\boxed{L_{LTE} < L_{LTE}^S \qquad L_{UMTS} \geq L_{UMTS}^S}$$

$$\boxed{L_{LTE} \geq L_{LTE}^S \qquad L_{UMTS} < L_{UMTS}^S}$$



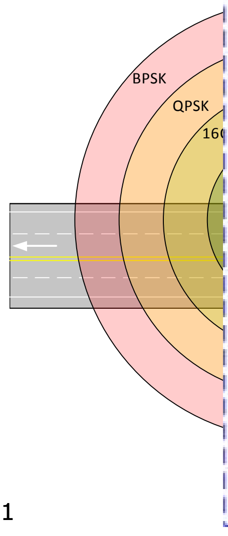
Phase 3: the Dynamic resource Allocations of UMTS and LTE Phase (DAP)

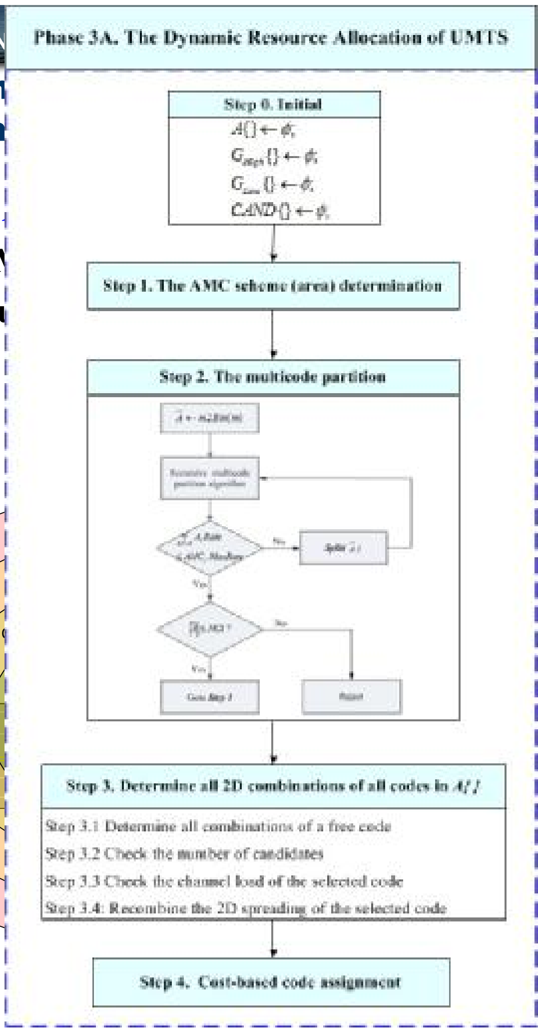


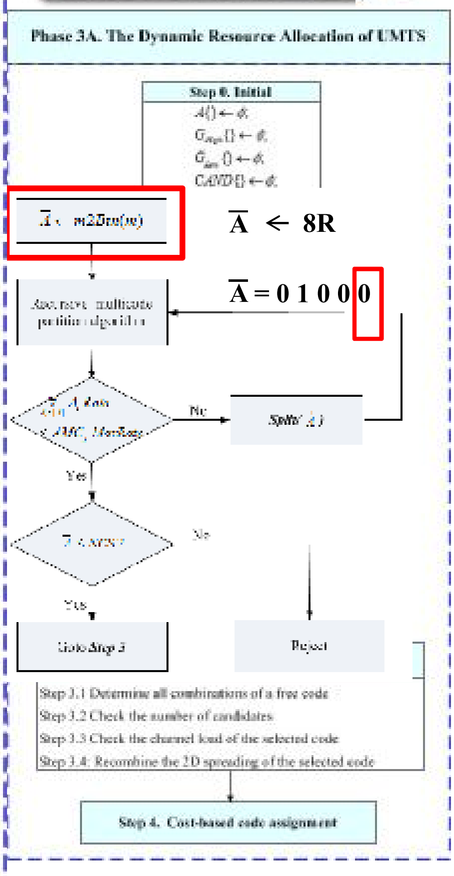


Phase 3: the Dynan UMTS and LTE Pha

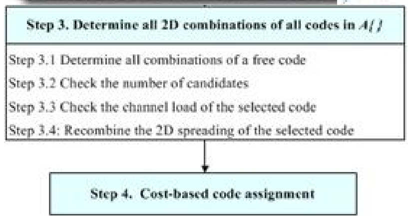
- UMTS Resource
  - Step 1. The AM
  - Step 2. The mu







Phase 3: the Dynamic resource Allocations of UMTS and LTE Phase (DAP) (cont.)



- Consists of four processes:
  1. to determine all combinations of a free channelization code
  2. to check the number of candidate
  3. to check the channel load of the selected code
  4. to recombine the 2D spreading of the selected code.

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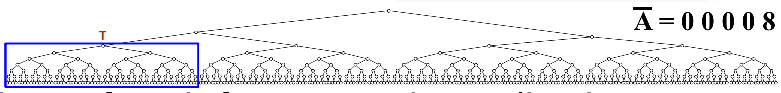
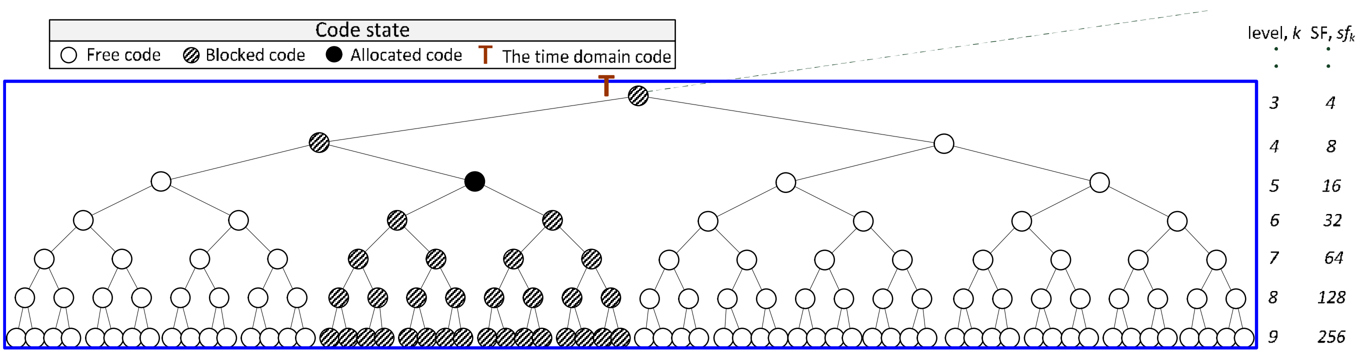
Step3.1 Determine all combinations of a free channelization code

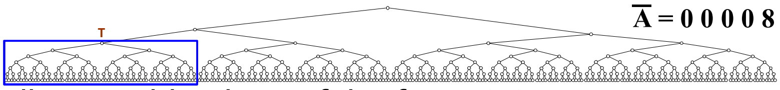


- all 2D spreading combinations of each free-state channelization code that is in $A\{\ \}$
- a lower channel load are then selected as the candidates based on two factors
  - the combination with the largest frequency spreading factor
  - the time domain code should not have a high channel load



Step3.1 Determine all combinations of a free channelization code

$\overline{\mathbf{A}} = 0\,0\,0\,0\,8$



- After determining all 2D spreading combinations of the free-state channelization codes, the combinations are prioritized into two groups according to the low and high thresholds of a channel load.

$$CL_{sf_{k_t},i_t} < CL_{sf_{k_t},Low}$$

0.375

$$G_{High}\{\} \leftarrow C_{sf_k,i} = C^T_{sf_{k_t},i_t} \cdot C^F_{sf_{k_f},i_f}$$

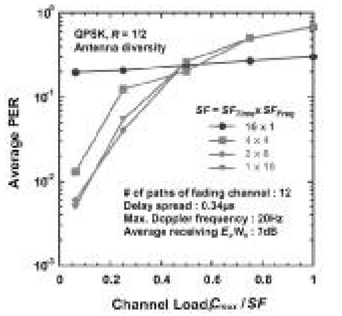
$$CL_{sf_{k_t},Low} \le CL_{sf_{k_t},i_t} < CL_{sf_{k_t},High}$$

$$G_{Low}\{\} \leftarrow C_{sf_k,i} = C^T_{sf_{k_t},i_t} \cdot C^F_{sf_{k_f},i_f}$$

$$CL_{sf_{k_t},i_t} > CL_{sf_{k_t},High}$$

0.75

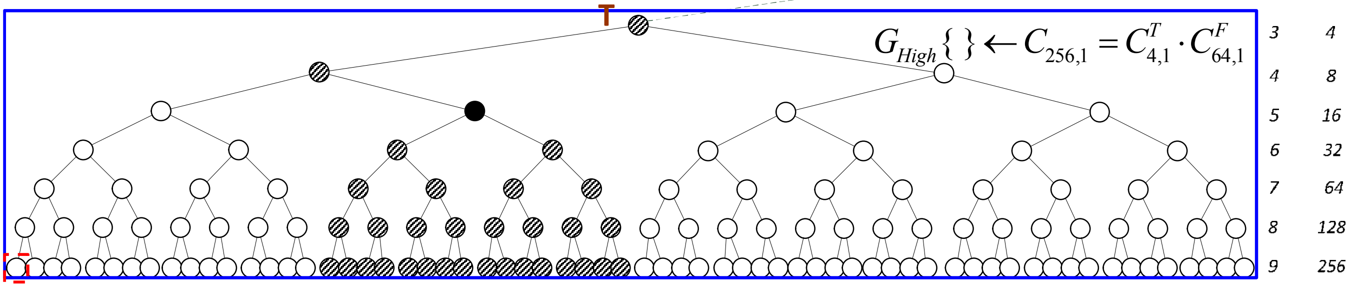
re-combination



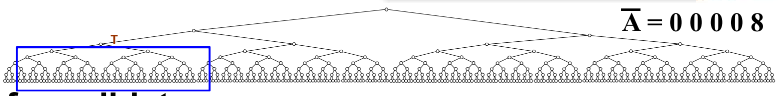
$$CL_{4,1} = \frac{16}{64} = 0.25$$

Code state			
○ Free code	Blocked code	● Allocated code	T The time domain code

$$G_{High}\{\} \leftarrow C_{256,1} = C^T_{4,1} \cdot C^F_{64,1}$$



$\overline{\mathbf{A}} = 0\,0\,0\,0\,8$



- **Step3.2 Check the number of candidates**
  - After performing ***Step 2*** and ***Step 3.1***, the number of candidates is at least one. If the size of the candidate set is equal to one, only one optimal 2D spreading exists

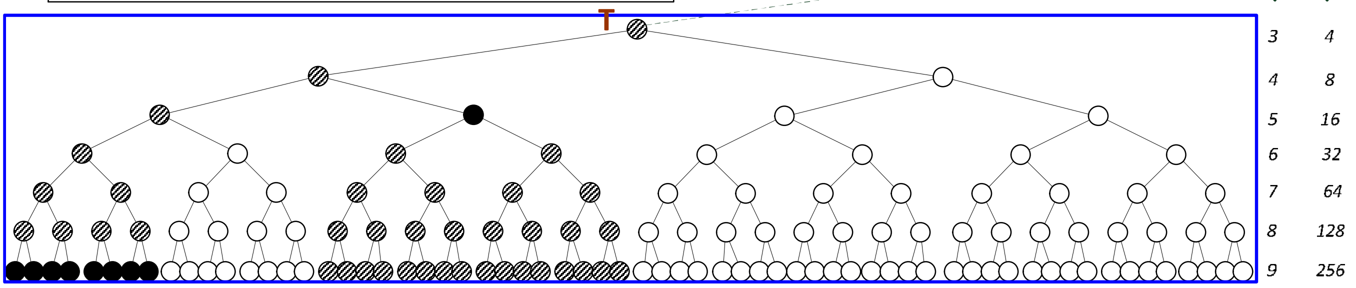
- **Step3.3 Check the channel load of the selected code**
  - The system checks whether the channel load of this combination exceeds the high threshold or not

$$CL_{sf_{k_t},i_t} > CL_{sf_{k_t},High}$$

0.75

$$CL_{4,1} = \frac{24}{64} = 0.39344$$

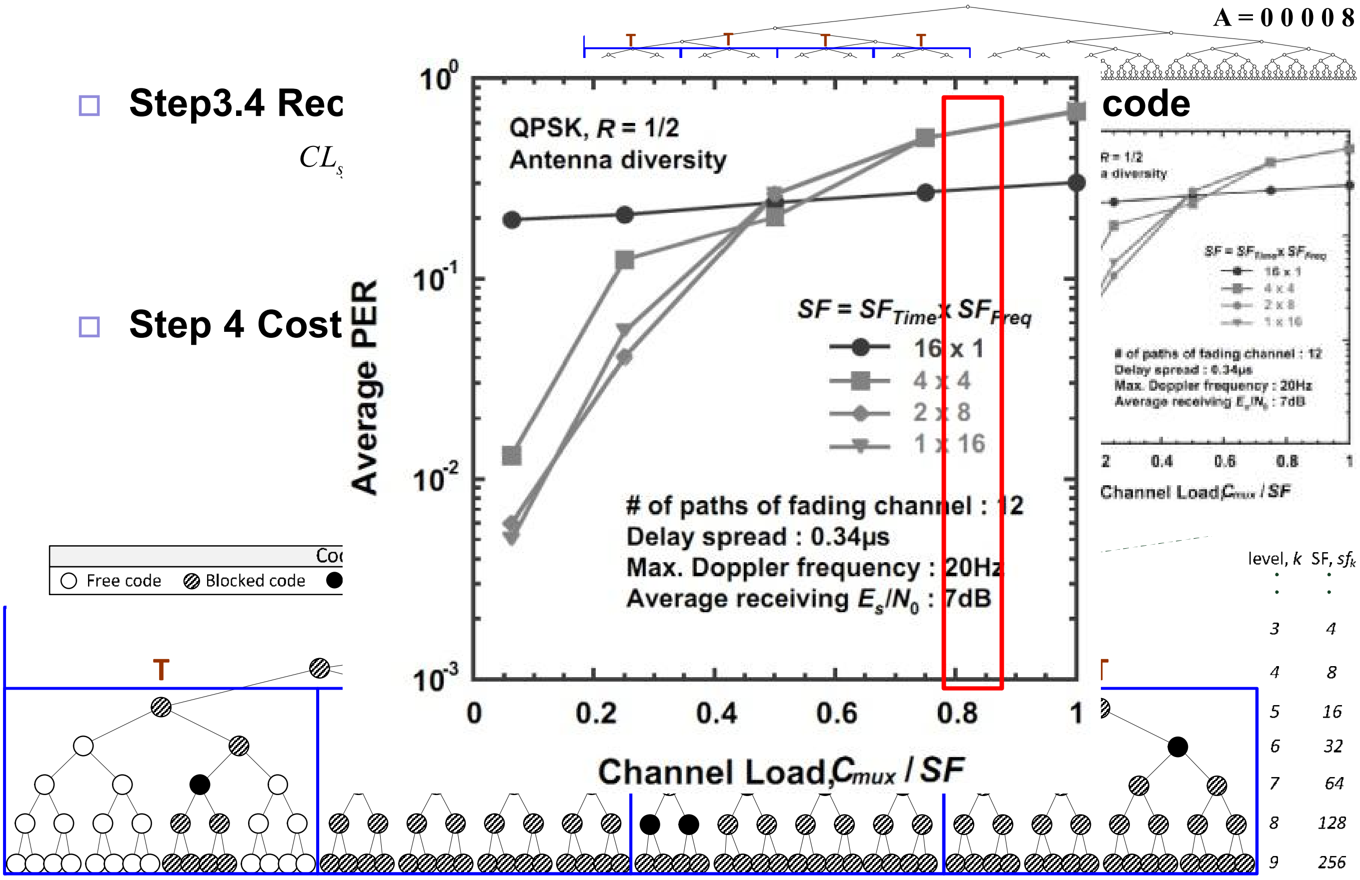
Code state			
○ Free code	Blocked code	● Allocated code	T The time domain code



- Step3.4 Rec ... code

CL_s

- Step 4 Cost



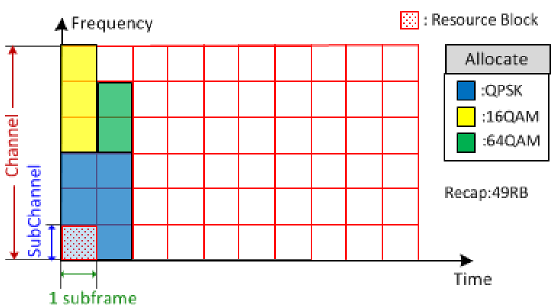
Phase 3: the Dynamic resource Allocations of UMTS and LTE Phase (DAP) (cont.)

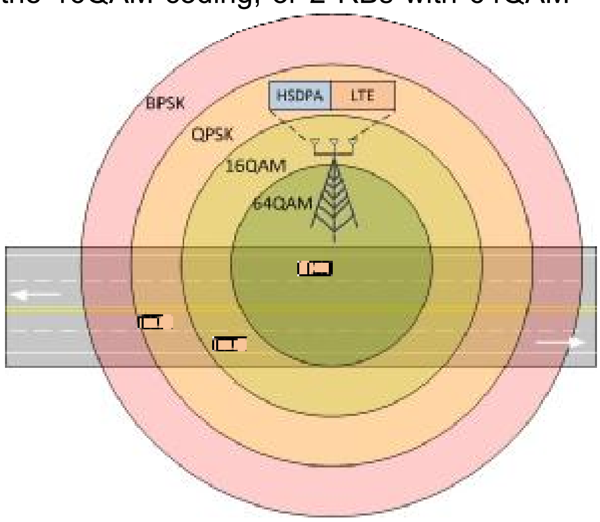
Phase 3B. The Dynamic Resource Allocation of LTE
Step.1 Determine user request and local.
Step.2 Assign user request.

- LTE Resource Allocation
  - A RB can adopt any type of AMC coding. Thus, the minimum and maximum data rates of a RB are 144 Kbps (QPSK) and 3.456 Mbps (64-QAM).

$$R_{RB} = 12(subcarriers)\cdot 12(symbols)\cdot 1(bits/symbol)\cdot 10(TTs)\cdot 100 = 144Kbps.$$

  - **example**
    - If a UE requires a 12R bandwidth. Then, the eNodeB can allocate 6 RBs with the QPSK coding, 3 RBs with the 16QAM coding, or 2 RBs with 64QAM coding.





Phase 3: the Dynamic resource Allocations of UMTS and LTE Phase (DAP) (cont.)

- the number of RBs needed for a 16R required rate under different AMC modulations can be determined

$$\mathrm{N}_{R_{RB}} = \frac{16 \cdot 144kbps}{864kbps} = \frac{2304kbps}{864kbps} = 2.666 \simeq 3RBs$$

- Although the eNodeB can allocate sufficient number of RBs for a 16R connection located in QPSK, it brings too much overhead and degrades the system reward and interface utilization

Modulation		Antenna	Bit/symbol	1 RB (Kbps)
QPSK	½	Single antenna	1	144
16QAM	½	Single antenna	2	288
16QAM	¾	Single antenna	3	432
64QAM	1	Single antenna	6	864
64QAM	1	2 x 2 MIMO	12	1728
64QAM	1	4 x 4 MIMO	24	3456

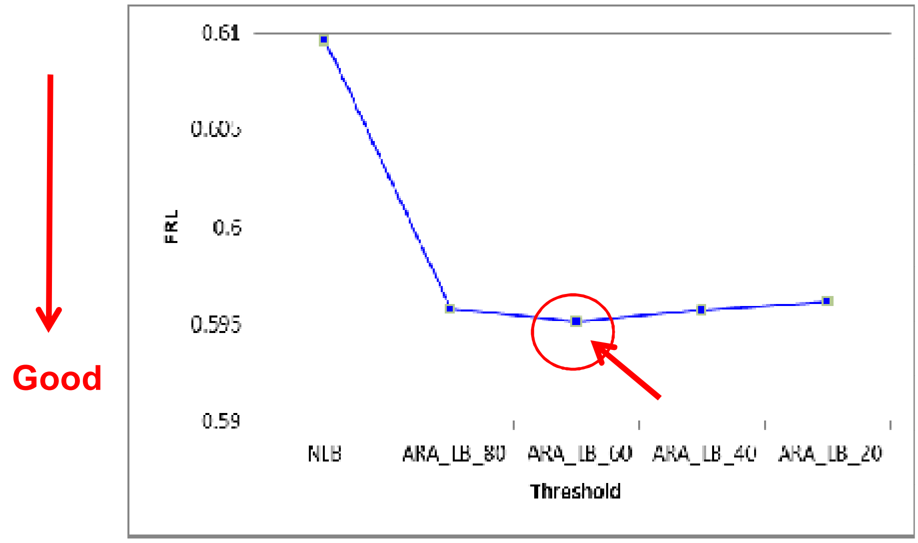
- For instance, we assume that MRB is set to 4. If a vehicle located at the QPSK location requires 16R data rate, the incoming connection will be rejected. The reason is the number of required RBs is 16 that is more than MRB

Parameters for simulations

	Parameters	Values
Network Model	LTE Capacity [39]	345.6 Mb/s
	UMTS Capacity	3.84 Mb/s=(256R)
	Number of rake-combiners (NCS)	1(single code), 2~8
	Total number of RBs	1000 RBs
	AMC coding schemes	QPSK/16QAM(1/2)//64QAM(1)
	Channel bandwidth	20 MHz
	Mode load threshold (S)	0.6
	Spreading factor, sf_k	1 ~ 256
	Time domain spreading factor, sf_{k_t}	4, 16
	Frequency domain spreading factor, sf_{k_f}	1~64
	Low threshold of the channel load in time domain, $CL^T_{sf_{k_t},Low}$	0.375, if $sf_k > sf_{k_t}$, 0.5, if $sf_k = sf_{k_t}$
	High threshold of the channel load in time domain, $CL^T_{sf_{k_t},High}$	0.75, if $sf_k > sf_{k_t}$, ∞, if $sf_k = sf_{k_t}$
	The weight parameter of the exponential smoothing model, α	0.85
Traffic Model	Number of traffic classes (m)	16 (i.e., 1~16)
	Average arrival rate (λ)	2 ~ 22
	Arrival rate (λ_m)	λ/m
	Bandwidth request (b_m)	$m \cdot 1R$
	Average holding time (μ)	1

Numerical results

- **A. The analysis of optimal threshold of load balancing**
  - FRL under different thresholds of load balancing



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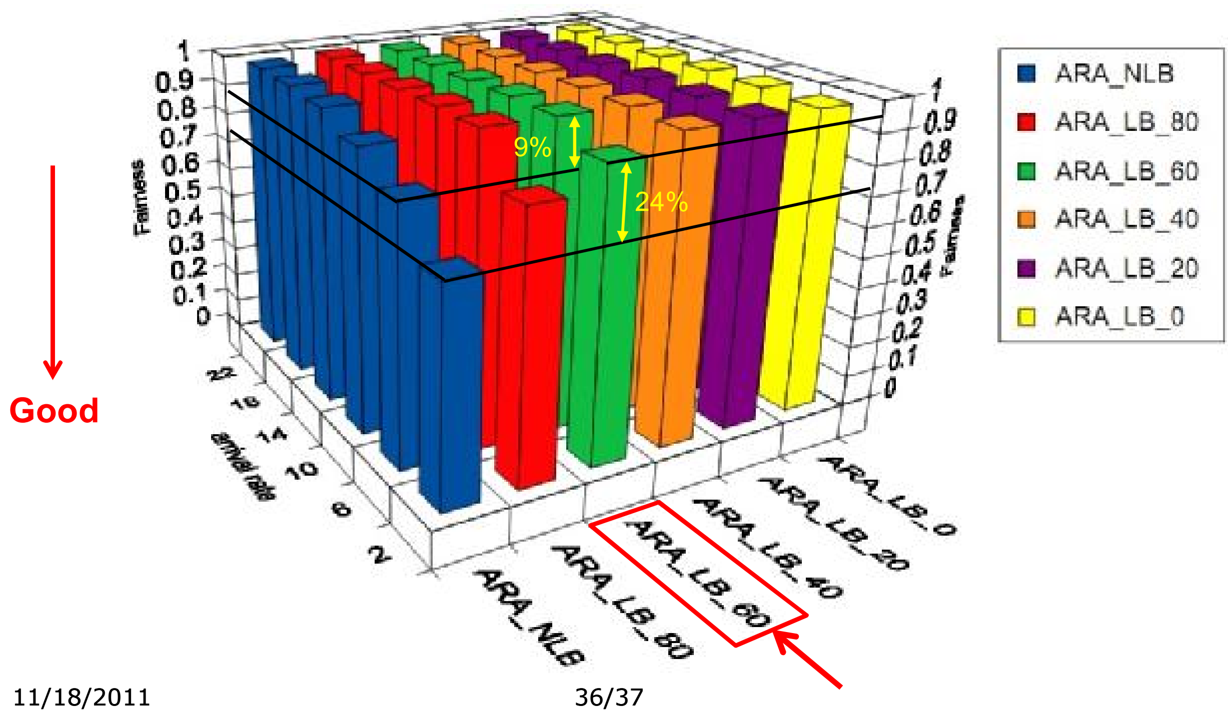
Numerical results (cont.)

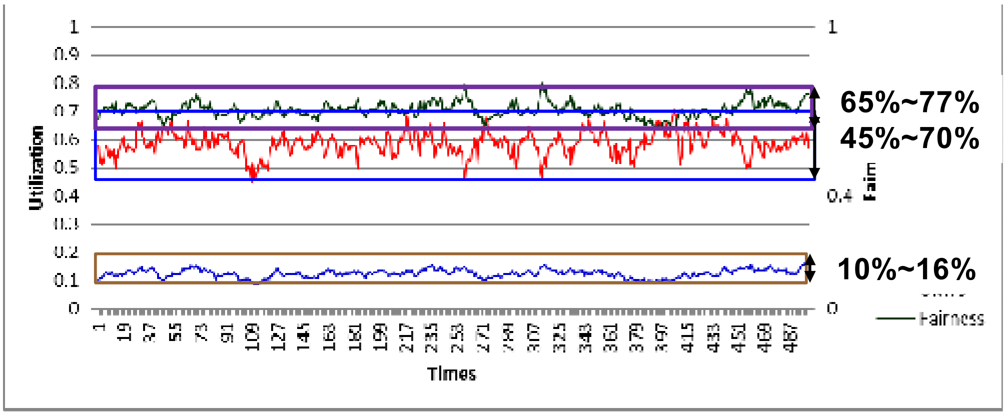
- **Fairness of different thresholds of the load balancing under various arrival rates**



Numerical results (cont.)

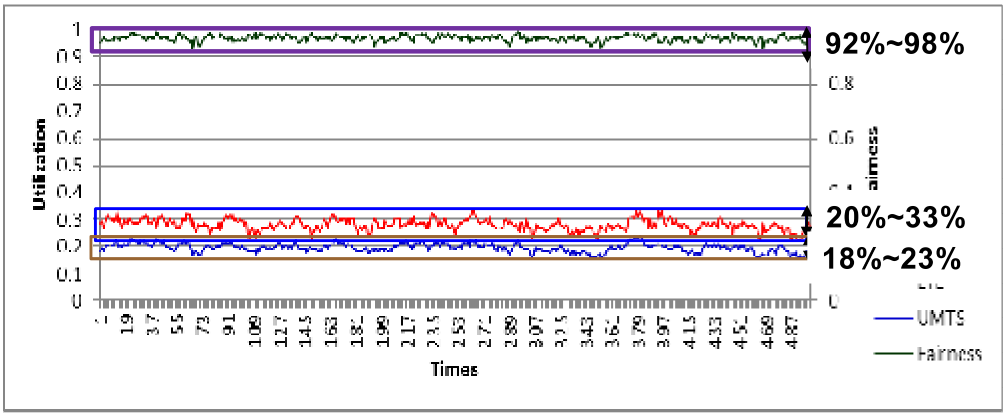
ARA_NLB

Good



ARA_LB_0

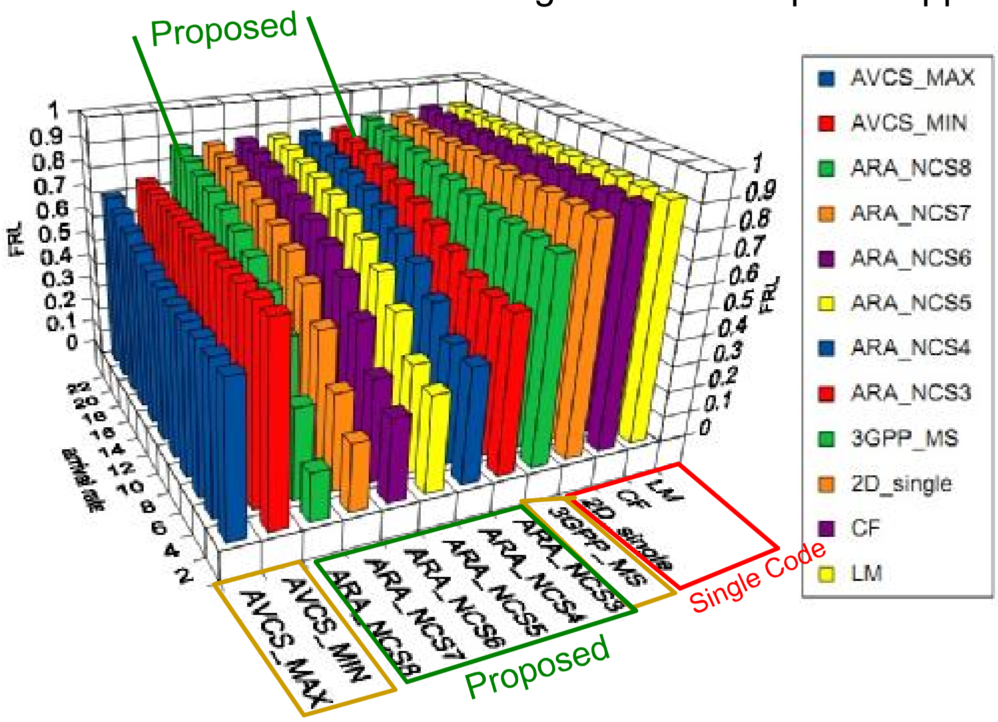
Good



Numerical results (cont.)

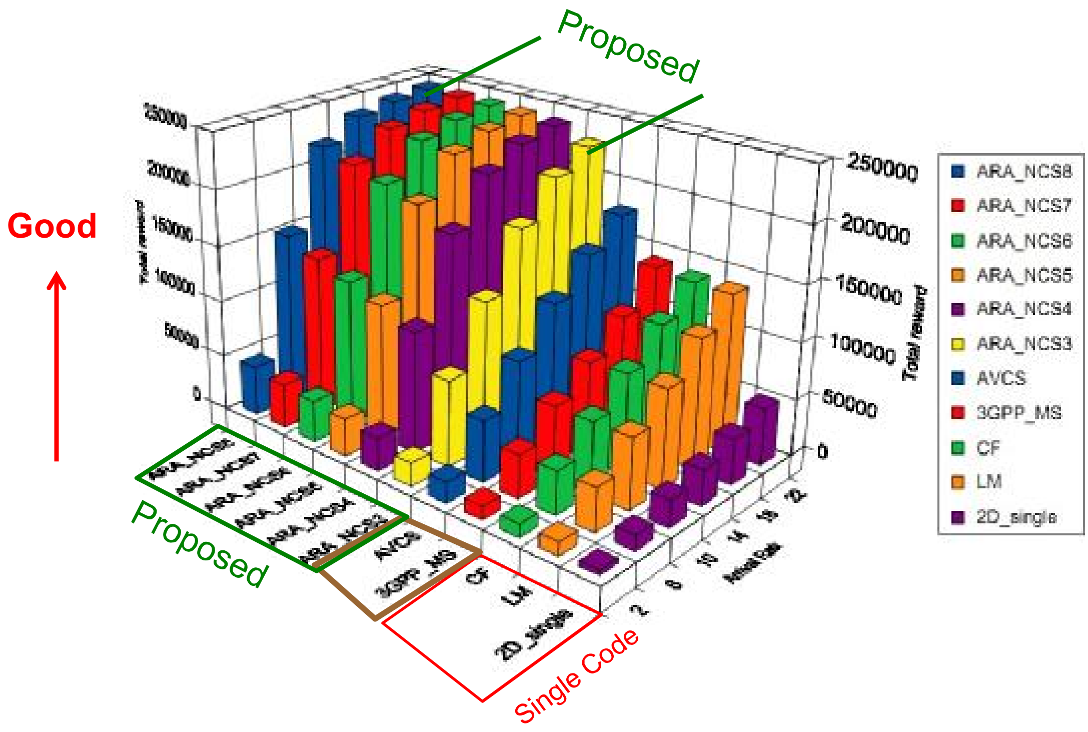
- B. Performance evaluations among different compared approaches

Good



Numerical results (cont.)

- Total reward under different arrival rates



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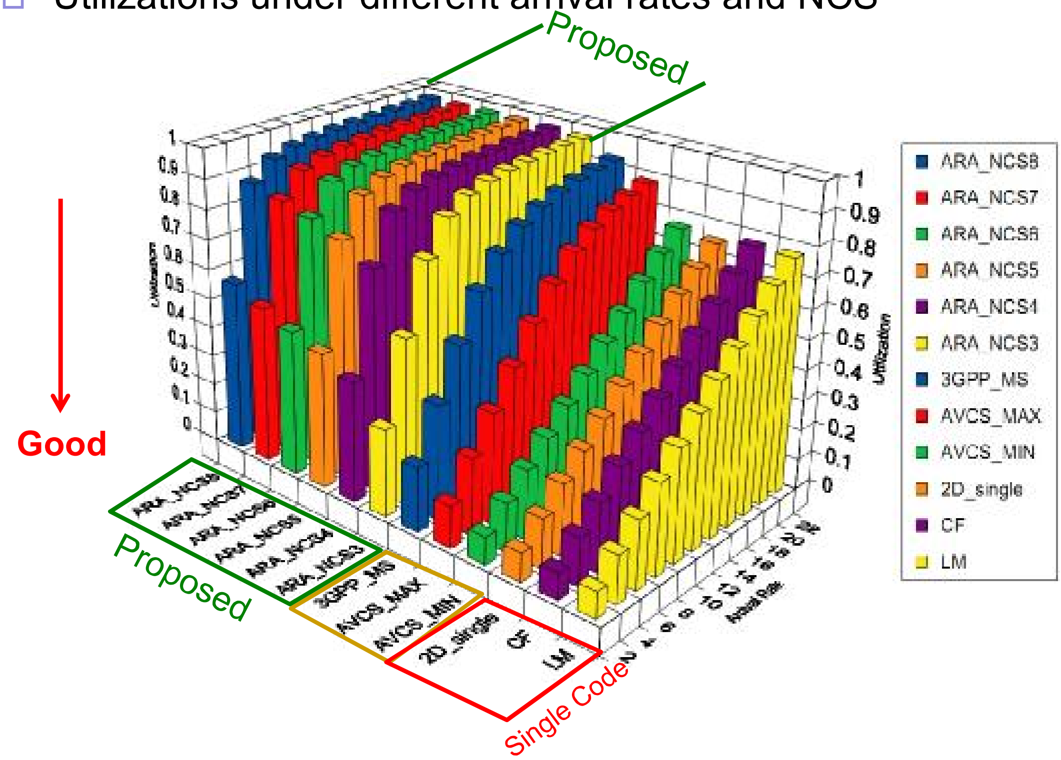
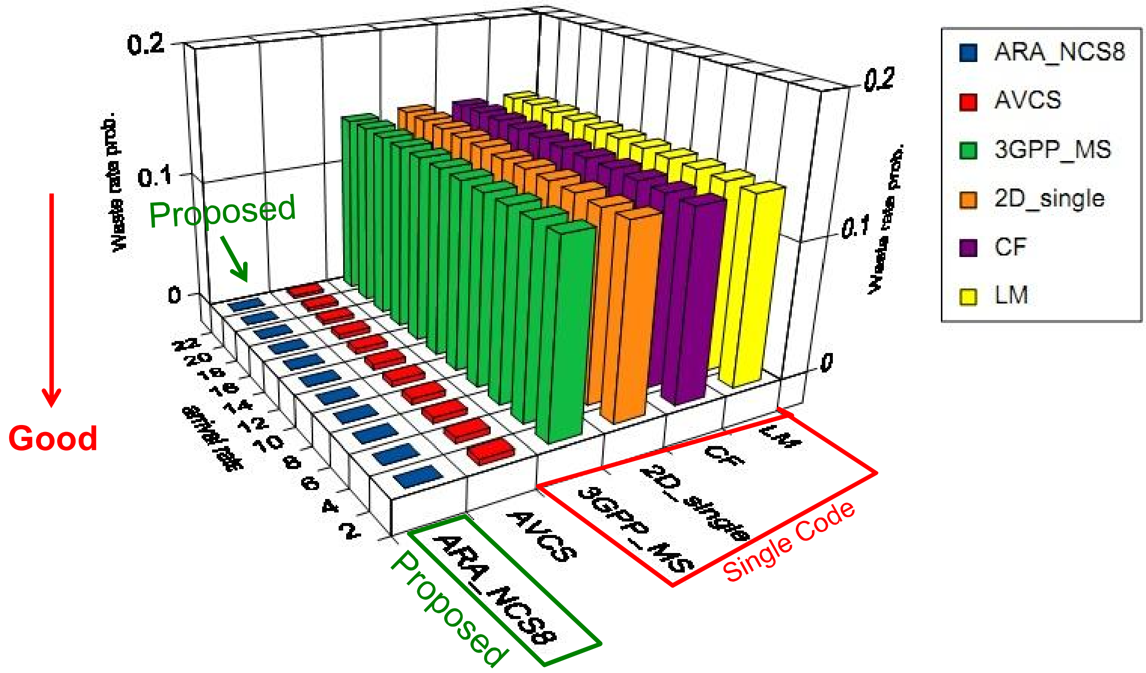
Numerical results (cont.)

- Utilizations under different arrival rates and NCS



Numerical results (cont.)

- Bandwidth waste rate of all compared approaches under different arrival rates



Conclusions

- the ARA approach can maximize reward, balance loads, and minimize bandwidth waste rate in 4G UMTS and LTE Communications.

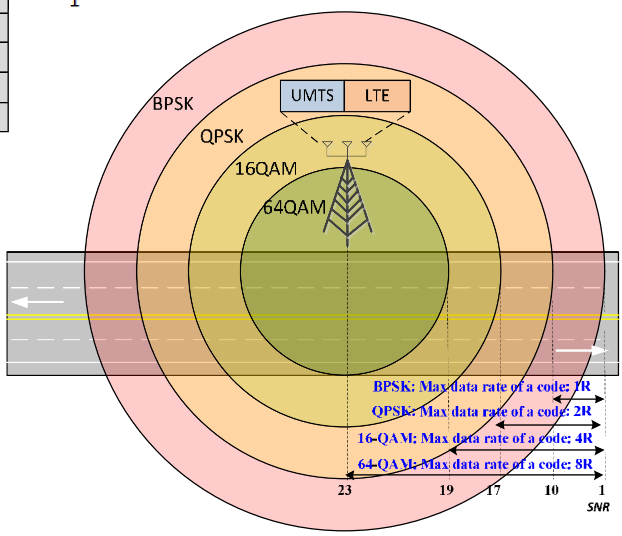
- this paper thus proposed the **A**daptive **R**adio-resource **A**llocation (**ARA**) approach that consists of three phases:
  - 1) the **L**oads of UMTS and LTE **D**etermination **P**hase (**LDP**),
  - 2) the connection **A**dmission control and **C**lassification **P**hase (**ACP**)
  - 3) the **D**ynamic resource **A**llocations of UMTS and LTE **P**hase (**DAP**).

- The first two phases: LDP and ACP efficiently achieve the load balancing feature.

Q & A
Thanks

Single assign system

			64QAM	16QAM	QPSK	BPSK	Reward loss
1	R	00001	can assign	can assign	can assign	can assign	0
2	R	00010	can assign	can assign	can assign	can't assign	0.25
3	R	00100	can assign	can assign	can't assign	can't assign	0.5
4	R	00100	can assign	can assign	can't assign	can't assign	0.5
5	R	01000	can assign	can't assign	can't assign	can't assign	0.75
6	R	01000	can assign	can't assign	can't assign	can't assign	0.75
7	R	01000	can assign	can't assign	can't assign	can't assign	0.75
8	R	01000	can assign	can't assign	can't assign	can't assign	0.75
9	R	10000	can't assign	can't assign	can't assign	can't assign	1
10	R	10000	can't assign	can't assign	can't assign	can't assign	1
11	R	10000	can't assign	can't assign	can't assign	can't assign	1
12	R	10000	can't assign	can't assign	can't assign	can't assign	1
13	R	10000	can't assign	can't assign	can't assign	can't assign	
14	R	10000	can't assign	can't assign	can't assign	can't assign	
15	R	10000	can't assign	can't assign	can't assign	can't assign	
16	R	10000	can't assign	can't assign	can't assign	can't assign	



Related Works

- The code allocation algorithms of the VSF-OFCDM scheme can be classified into three types:
  - **the allocations of 2D-based single code [13], [14]**
    - [13] Y. Zhou, J. Wang and T.-S. Ng, “Downlink Transmission of Broadband OFCDM Systems-Part V: Code Assignment,” IEEE Transactions on Vehicular Technology, Vol. 7, No. 11, pp. 4546-4557, Nov. 2008.
    - [14] B.-J. Chang, and C.-H. Wu, “Adaptive Load Balancing MDP-Based Approach of Two-Dimensional Spreading for VSF-OFCDM in 4G Next-Generation Cellular Communications,” IEEE Transactions on Vehicular Technology, Vol. 58, No. 3, pp. 1143-1156, March. 2009. [2D-single]
  - **single code [15]-[21]**
    - CF
    - LM

    Advantage

    Use frequency and time domain to decrease packet error rate.

    Disadvantage

    they suffer from wasting the bandwidth when the request data rate does not meet the data rate of a channelization code of the VSF-OFCDM code

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Related Works

- multicode [22]-[29], [38]
  - [28] V. Balyan and D.S. Saini, “An Efficient Multi Code Assignment Scheme to Reduce Call Establishment Delay for WCDMA Networks,” *2010 1st International Conference on Parallel Distributed and Grid Computing (PDGC)*, pp. 278-283, Oct. 2010. [AVCS]
  - [38] TR 25.922 Version 7.1.0, “Radio resource management strategies (Release 7),” *3GPP*, pp. 7-91, Mar. 2007 [3GPP_MS]

  Advantage

  main objective is to overcome the bandwidth waste rate resulted from the single code allocation

  Disadvantage

  The most important process in the multicode allocation is to partition the required data rate of a new incoming connection according to the residual radio resources