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Title	**Proposed Inputs to IEEE 802.18 on IMT-Advanced Requirements**
Date Submitted	**2007-03-10**
Source(s)	Sassan Ahmadi, Intel Corporation sassan.ahmadi@intel.com
Re:	Call for contributions regarding requirements for IMT-Advanced systems, 2/15/2007
Abstract	This document contains proposed system and service requirements for IMT-Advanced.
Purpose	For discussion and approval by WG 16 and forward to WG 18 for consideration
Notice	The IEEE 802.18 TAG is seeking to coordinate content that can be contributed to ITU-R WP 8F regarding technical requirements for IMT-Advanced. This document has been prepared to assist IEEE 802.18 in compiling system requirements for IMT-Advanced. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.
Release	
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PROPOSED REQUIREMENTS FOR IMT-ADVANCED SYSTEMS

This document contains changes and updates to *DRAFT [Report on] Requirements related to technical system performance for IMT-Advanced Radio interface(s) [IMT.TECH]* prepared by Working Party 8F in January 2007.

Proposal

System requirements for IMT-Advanced cellular systems

Attachments:
Enclosed

INTERNATIONAL TELECOMMUNICATION UNION

RADIOCOMMUNICATION STUDY GROUPS

21ST MEETING OF WORKING PARTY 8F
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PROPOSED UPDATES/CHANGES TO DRAFT [REPORT ON] REQUIREMENTS RELATED TO TECHNICAL SYSTEM PERFORMANCE FOR IMT-ADVANCED RADIO INTERFACE(S) [IMT.TECH]

TABLE OF CONTENTS

1 Introduction

[Editor's note:

Text will be imported from the common text which is discussed in WG-SERV.]

A set of changes are proposed to ensure that IMT-Advanced system requirements while forward looking are realistic and achievable in the timelines set forth for IMT-Advanced radio access technologies.

The sections that do not contain any requirements are marked as 'informative'. The term '3G systems' in this document refers to IMT-2000 family of radio access technologies, IEEE 802.16, etc.

2 Scope and Purpose

IMT.TECH describes requirements related to technical system performance for IMT-Advanced candidate radio interfaces. These requirements are used in the development IMT.EVAL, and will be attached as Annex 4 to the Circular Letter to be sent announcing the process for IMT-Advanced candidacy.

IMT.TECH also provides the necessary background information about the individual requirements (technology enablers) and the justification for the items and values chosen. Provision of such background information is needed for wider reference and understanding.

IMT.TECH is based on the ongoing development activities from external research and technology organizations. The information in IMT.TECH will also feed in to the IMT.SERV document. IMT.TECH provides the radio interface requirements which will be used in the development of IMT.RADIO

3 Related Documents

Recommendation ITU-R ~~M~~[IMT.SERV]

Recommendation ITU-R M.1645

Recommendation ITU-R M.1768

Report ITU-R M.2038

Report ITU-R M.2072

Report ITU-R M.2074

Report ITU-R M.2078

Report ITU-R M.2079

Recommendation ITU-R M.1224

Recommendation ITU-R M.1225

[Recommendation ITU-T Q.1751

Recommendation ITU-T Q.1761

Recommendation ITU-T Q.1711

Recommendation ITU-T Q.1721

Recommendation ITU-T Q.1731

Recommendation ITU-T Q.1703]

[Editor's note: Document to be added]

4 General Requirements

[Editor's note: This section is for describing general requirements for cellular systems including IMT which are requested by market not only developed but also developing countries]

The following are the general system requirements and features that IMT-Advanced system shall support:

- Higher spectral efficiencies and peak data rates
- Lower latencies (air-link access latency, [Inter-FA HO, Intra-FA HO, inter-RAN HO] latencies) to enable new delay-sensitive applications.
- Support of larger contiguous/non-contiguous bandwidths in the excess of 20 MHz
- Mobility Support ~~speed~~: Cellular systems including IMT-Advanced are required to support the environments described in following:
  - ~~-~~Stationary (Fixed applications) (i.e. can be used as a FWA systems)
  - ~~-~~Pedestrian (~~Walking speed of~~Pedestrian speeds up to ~~several~~10 ~~km/Hr~~km/h)
  - ~~-~~Typical Vehicular (~~Automobile~~ Vehicular speeds up to 120 ~~of one hundred and several tens km/Hr~~km/h)
  - - High Speed Vehicular (~~High speed train~~Vehicular speeds up to ~~500km~~-350 ~~/Hr~~km/h)
  - Optimized system performance for low mobility environments
  - ~~-~~Seamless application connectivity to other mobile networks~~/PSTN/ISDN~~ and other IP networks (global roaming capabilities).
- ~~Potential to s~~Support for larger cell sizes and improved cell-edge performance
- ~~Cheap~~ Low-cost and low-complexity terminals for worldwide use
- ~~-~~ Mobile user interface
- ~~-~~ Ubiquitous Access
- Support of integrated relay architectures (multi-hop topologies)
- Improved unicast and multicast broadcast services (relative to 3G systems)
- Provision for PAN/LAN/WAN Co-location / Coexistence

5 Technical Requirements

[Editor Note: This chapter specifies the technical independent requirements that determine the performance of the IMT-Advanced systems.]

5.1 ~~Technological items required to describe candidate air interface~~Characterization of IMT-Advanced systems

[Editor's note: This section is for listing up technology enablers which need to be described in the candidate air interface proposal for IMT-Advanced and also the general explanation why those each technology enablers are important to be described.]

5.1.1 Radio transmission technologies functional blocks

5.1.1.1 Multiple access methods

[The choice of the multiple access technology has major impact on the design of the radio interface. For instance, OFDMA, CDMA and also Single-carrier/Multi-carrier operation]

The IMT-Advanced systems may utilize various multiple access schemes for the downlink and the uplink. It is desirable that a symmetric multiple access system be used for the down link and the uplink to reduce the complexity of the multi-radio terminals and to allow reuse of the functional blocks in the baseband through reconfiguration.

5.1.1.2 Duplex ~~methods~~schemes

[The choice of the duplexing technology mainly affects the choices of the RF-channel bandwidth and the frame length. Duplexing technology may be independent of the access technology since for example either frequency division duplex (FDD), time division duplex (TDD) or half-duplex FDD may be used. It also affects band allocations, sharing studies, and cell size.]

The IMT-Advanced systems shall provide support for both paired (FDD) and unpaired (TDD) spectrum. The IMT-Advanced systems should further enable duplexer-free FDD (H-FDD) implementation option for clients operating in FDD networks.

The commonalities between FDD and TDD modes of operation in terms of functional elements and features shall be maximized to reduce complexity of terminals supporting both schemes.

5.1.1.3 Operating bandwidth

The IMT-Advanced systems shall support scalable bandwidths of 5 to 20 MHz. The support for larger bandwidths in excess of 20 MHz in the form of contiguous and/or non-contiguous bands should also be considered.

Support for unequal (asymmetric) DL and UL bandwidths (e.g., DL 20 MHz and UL 10 or 5 MHz) should be considered for FDD systems.

Terminals with different bandwidths shall be supported for TDD/FDD systems.

Terminals and base stations shall support a minimum bandwidth of 5 MHz (for both TDD and FDD duplex schemes).

5.1.1.4 Baseline antenna configuration

The IMT-Advanced systems shall support the baseline antenna configuration of DL 2x2 and UL 1x2. Other antenna configurations such as DL: 4x2, 2x4, 4x4 and UL: 1x4, 2x2, 2x4, 4x4 should also be supported.

5.1.1.5 Modulation scheme

[The choice of the modulation technology depends mainly on radio environment and the spectrum efficiency requirements.]

The following table summarizes modulation schemes that are typically used for the downlink and uplink in IMT-Advanced systems. The modulation and coding scheme shall be adapted to the radio channel conditions.

Modulation Scheme	Downlink	Uplink
	[BPSK], QPSK, 16 QAM, 64 QAM	[BPSK], QPSK, 16 QAM, 64 QAM

5.1.1.6 Error control coding scheme

[The choice of the error control coding affects qualities of air link, throughput, terminal complexity, and also delay performance of communications.]

The following table summarizes coding schemes (coding rates and repetition) that are typically used for the downlink and uplink in IMT-Advanced systems. The modulation and coding scheme shall be adapted to the radio channel conditions.

Coding Scheme	Coding Rate	Repetition
CTC (Convolutional Turbo Code)	1/5, 1/2 , 2/3, 3/4 , 5/6	x1, x2, x4, x6
BTC (Block Turbo Code)	1/5 , 1/3	x1, x2, x4, x6
CC (Convolutional Code)	1/2 , 2/3, 3/4 , 5/6	x1, x2, x4, x6
LDPC (Low Density Parity Check Codes)	1/2 , 2/3, 3/4 , 5/6	x1, x2, x4, x6

5.1.1.7 Physical channel structure and multiplexing (informative)

[The physical channel is a specified portion of one or more radio frequency channels as defined in frequency, time spatial and code domain.]

5.1.1.8 Frame Structure

[The frame structure depends mainly on the multiple access technology (e.g. OFDMA, TDMA, and CDMA) and the duplexing ~~technology~~ schemes (e.g. FDD, TDD). Commonality should be maximized by maintaining the same frame structure ~~whenever~~ wherever possible. That is, data fields identifying physical and logical channels, as well as the frame length should be maintained when possible.]

The design of the frame structure should consider shorter TTI (transmission time interval) and shorter RTT (round trip time) to allow reduced air link latency and HO. Typical radio frame lengths include but not limited to 1, 2, 5, and 10 ms.

5.1.1.9 [FFT size, Chip rate etc.]

The FFT size and chip rate (sampling frequency) vary in different radio access technologies that are compliant with IMT-Advanced requirements. However, IMT-Advanced systems shall support bandwidth scalability such that the size of the FFT and sampling frequency (chip rate in CDMA systems) are scaled up with increasing bandwidth. The following table provides typical numerology for a scalable OFDMA system as an example:

Attribute	Numerical/Parametric Value		
Transmission Bandwidth BW (MHz)	5	10	20
Over-sampling Factor	n	n	n
Sampling Frequency F_p MHz (Chip Rate Mcps)	n*BW	n*BW	n*BW
FFT Size N_{FFT}	512	1024	2048
Sub-Carrier Spacing kHz	F_p/N_{FFT}		
Useful OFDM Symbol Duration T_b	1/		
Guard Time	T_g (a fraction of T_b typically 1/32 to 1/4)		
OFDMA Symbol Duration (s)	$T_s = T_b + T_g$		
Frame Size (ms)	T_f		
Number of OFDM Symbols per Frame			

5.1.2 Other functional blocks

5.1.2.1 Source coder (informative)

[The choice of the source coder may generally be made independently of the access method.]

The IMT-Advanced system shall support a variety of services and applications such as VoIP, video streaming, mobile TV, etc. For each service/application and depending on several design considerations such as QoS, data rate, delay, etc. there are standard source coders that can be utilized. The performance of IMT-Advanced systems shall not be dependent on any specific source coder.

5.1.2.2 Interworking (informative)

[The interworking function (IWF) converts standard data services to the rates used internally by the radio transmission subsystem. The IWF feeds into the channel coder on the transmit side and is fed from the channel decoder on the receiver side. It also incorporates some functionality to deal with the applications such as voice, images, etc.]

5.1.3 Latency

[The latency is important factor especially if delay sensitive communication required.] Latency should be further reduced as compared to 3G systems for all aspects of the system including the air link, state transition delay, access delay, and handover.

The following latency requirements shall be met by the system, under light loading assuming no signaling/MAC message retransmission.

Latency Metric	Requirement	Comments
IDLE_STATE to ACTIVE_STATE	< 100 ms	The time it takes for a device to go from an idle state (fully authenticated/registered and monitoring the control channel) to when it begins exchanging data with the network on a traffic channel or timeslot measured from the paging indication (i.e. not including the paging period).
SLEEP_STATE to ACTIVE_STATE	< 10 ms	
Transmission Latency – Uplink	< 10 ms	The one-way transit time between the start of a small IP data packet transmission from the MS MAC layer and its arrival at the BS MAC layer for a high priority service assuming all radio resources have been previously assigned.
Transmission Latency – Downlink	< 10 ms	The one-way transit time between the start of a small IP data packet transmission from the BS MAC layer and its arrival at the MS MAC layer for a high priority service assuming all radio resources have been previously assigned.
Scheduling Latency – Uplink	< 15 ms	The time between the arrival of a data packet at the MS and the start of its transmission for a high priority service assuming all radio resources have been previously assigned.
Handoff interruption time (intra FA)	< 50 ms	The time between the point when an MS makes connection with a target handoff channel and when it breaks connection with its previous operating channel

		(Handoff between two sectors operating in the same frequency assignment).
Handoff interruption time (inter FA)	< 150 ms	The time between the point when an MS makes connection with a target handoff channel and when it breaks connection with its previous operating channel (Handoff between two sectors operating in different frequency assignments).
Initial System Entry Time	(a) < 5 s (b) < 60 s	The time for a new device to complete network entry with probability > 0.9, including scanning, receiving DL signal and required management messages, and performing system entry for (a) when the device is powered on in the same network it was operating last time (including neighboring cells), and (b) when the device is powered on in a new network.

5.1.4 QoS management scheme

[The QoS is important factor especially the applications which are originally supported by circuit switched network in delay/jitter.]

The IMT-Advanced systems shall support improved QoS classes, enabling a more optimal matching of service, application and protocol requirements (including higher layer signaling) to RAN resources and radio characteristics. This includes enabling new applications such as interactive gaming. The IMT-Advanced systems shall provide

- a greater ability to simultaneously support a wide range of multimedia services,
- enhanced management of different quality of service levels

5.1.5 Security and Privacy ~~Aspects~~

[The secure communication should be achieved at least the same level as the IMT-2000.]

The following are the requirements for Secrecy and Privacy:

- More powerful, enhanced (high-speed/small-size and low-power) confidentiality and integrity protection (encryption) for traffic transmission, MAC management messages, and control information;
- More efficient, robust user/device authentication scheme; Location privacy scheme; and Reliable and flexible service availability protection scheme.

The following are the requirements for Service Security

- Authentication and authorization of subscribers to each service shall be provided
- All signaling and user traffic related to services shall be confidentiality- and integrity- protected
- It shall be possible to apply different levels of security to different sessions after some negotiation during the signaling setup

- A single sign-on solution that minimizes the number of times that protection is applied when a user is accessing a service, without reducing the security level, is highly desirable.

The following are the requirements for Interworking Security:

- Delay constrained handover and roaming support without changing the security level (Especially, seamless mobility across heterogeneous networks with the negotiation of security mechanisms/algorithms); and Minimum performance/capacity degradation due to the security feature provisioning]

5.1.6 Capacity considerations/ Supported user density

[Requirements that specify how many users could be supported in different scenarios, e.g., rural, urban and hotspot.]

5.1.7 Network Topology

[Proposed radio interface technology need to be considered for applying to Single-hop mode, Multi-hop mode, mesh mode and Peer to peer mode.]

The IMT-Advanced systems should provide support for multi-hop topologies. However, the system requirements described in this document shall be met without the use of relay stations; i.e., the baseline architecture/topology of IMT-Advanced systems does not include relay stations.

IMT-Advanced systems shall support different cell sizes which are expected for cellular layer systems. The cell radius and coverage requirements are as follows:

IMT-Advanced systems shall support legacy cell sizes allowing for co-location of 3G deployments. In addition, larger cell sizes should be considered. Cell sizes up to 30 km should be supported with limited performance degradation. Cell sizes up to 100 km should not be precluded from the standard. Support for these larger cell sizes should not compromise the performance of smaller cells.

5.1.8 Mobility management and RRM

[Centralized/Distributed RRM, Intra-FA, Inter-FA, and Inter-RAT ~~spectrum sharing/~~mobility management need to be considered.]

5.2 Functional and performance requirements (Required technology items for evaluation)

5.2.1 Peak Data Rates and Spectrum efficiency~~/ Coverage efficiency~~

[The supported information transmission rate under some constrains, e.g., bandwidth, area, time and system load.]

5.2.1.1 Peak data rates

The requirements for peak data rates in the downlink and uplink are captured in the following table. These requirements shall be met with the baseline antenna configuration (see Section 5.1.1.4 ~~5.1.1.4~~)). For TDD systems, these requirements shall be calculated for the DL and UL based on 1:0 and 0:1 DL:UL ratios, respectively.

Key Performance Characteristic	Required Value	Comments
DL Peak Data Rates		
Peak (stationary/indoor)	> 64 Mbps	Assuming a 10 MHz operating bandwidth (unpaired) This requirement shall be met with the baseline antenna configuration. Average Instantaneous Data Rate DL > 20 Mbps, where average instantaneous implies average over the cell area.
Peak (pedestrian)	> 64 Mbps	
Peak (vehicular)	> 40 Mbps	
Peak (stationary/indoor)	> 128 Mbps	Assumes a 20 MHz operating bandwidth This requirement shall be met with the baseline antenna configuration. Average Instantaneous Data Rate DL > 40 Mbps, where average instantaneous implies average over the cell area.
Peak (pedestrian)	> 128 Mbps	
Peak (vehicular)	> 80 Mbps	
UL Peak Data Rates		
Peak (stationary/indoor)	> 28 Mbps	Assuming a 10 MHz operating bandwidth (unpaired) This requirement shall be met with the baseline antenna configuration. Average Instantaneous Data Rate UL > 10 Mbps, where average instantaneous implies average over the cell area.
Peak (pedestrian)	> 28 Mbps	
Peak (vehicular)	> 18 Mbps	
Peak (stationary/indoor)	> 56 Mbps	Assuming a 20 MHz operating bandwidth. This requirement shall be met with the baseline antenna configuration.
Peak (pedestrian)	> 56 Mbps	

Peak (vehicular)	> 36 Mbps	Average Instantaneous Data Rate UL > 20 Mbps, where average instantaneous implies average over the cell area.

5.2.1.2 Spectrum efficiency

The requirements for the peak, sustained, and equal data spectral efficiencies and sector throughput for the mobile and base stations (whichever applies) are as follows. These requirements shall be met with the baseline antenna configuration (see Section 5.1.1.4 ~~5.1.1.4~~).

Performance Metric	**Required Value**	**Comments**
DL Data Rates		
Peak Spectral Efficiency/Sector (Full-Buffer Data Traffic)	> 6.4 bps/Hz/Sector	The maximum achievable number of successfully transmitted information bits per second per Hz that a sector can serve in a fully loaded network with full-buffer data traffic. This metric is separately provided for uplink and downlink by only considering the PHY-related (L1) overhead (separately for each link).
Sustained Spectral Efficiency (Full-Buffer Data Traffic)	> 7.5 bps/Hz/Cell	The number of successfully transmitted information bits per second per Hz that a site can serve for a given DL:UL ratio, given number of users, site-to-site distance, and a given fairness and delay criterion in a fully loaded network with full-buffer traffic. This metric is separately provided for uplink and downlink by considering both PHY- and MAC-related (L1+L2) overhead (separately for each link).
Sector Throughput DL:UL=2:1 for TDD duplex scheme, 10 MHz bandwidth	> 16 Mbps	The number of successfully transmitted information bits per second that a sector can serve for a given DL:UL ratio, a given number of users, site-to-site distance, and a given fairness and delay criterion in a fully loaded network with full-buffer traffic. This metric is separately provided for uplink and downlink by considering both PHY- and MAC-related (L1+L2) overhead (separately for each link).
Equal Data Spectral Efficiency (bps/Hz/Sector)	TBD	It is the harmonic mean of the throughput divided by the band width. Assume total bandwidth W, # of users *N* with throughput *S1, S2, ... SN,* hence $SE_{ED}=(N/W)*1/(1/S1+1/S2+...+1/SN)$
UL Data Rates		
Peak Spectral Efficiency (Full-Buffer Data Traffic)	> 3 bps/Hz/Sector	The maximum achievable number of successfully transmitted information bits per second per Hz that a sector can serve in a fully loaded network with full-buffer data traffic. This metric is separately provided for uplink

Traffic)		and downlink by only considering the PHY-related (L1) overhead (separately for each link).
Sustained Spectral Efficiency (Full-Buffer Data Traffic)	> 3.5 bps/Hz/Cell	The number of successfully transmitted information bits per second per Hz that a site can serve for a given DL:UL ratio, given number of users, site-to-site distance, and a given fairness and delay criterion in a fully loaded network with full-buffer traffic. This metric is separately provided for uplink and downlink by considering both PHY- and MAC-related (L1+L2) overhead (separately for each link).
Sector Throughput DL:UL=2:1 for TDD duplex scheme, 10 MHz bandwidth	> 4 Mbps	The number of successfully transmitted information bits per second that a sector can serve for a given DL:UL ratio, a given number of users, site-to-site distance, and a given fairness and delay criterion in a fully loaded network with full-buffer traffic. This metric is separately provided for uplink and downlink by considering both PHY- and MAC-related (L1+L2) overhead (separately for each link).
Equal Data Spectral Efficiency (bps/Hz/Sector)	TBD	It is the harmonic mean of the throughput divided by the band width. Assume total bandwidth W, # of users *N* with throughput *S1, S2, ... SN,* hence $SE_{ED}=(N/W)*1/(1/S1+1/S2+...+1/SN)$

5.2.2 Mobility

The IMT-Advanced systems should include air-interface features that would enable the seamless mobility with 3G systems. This requirement is intended to address additional air-link requirements beyond those covered by the IEEE 802.21 working group. For example, specific methods for scanning and system discovery should be considered as part of the IMT-Advanced system medium access control. Finally, requirements for handoff of broadcast services should also be defined.

The expectations for performance should tiered based on mobility speeds and prioritized in order to achieve the optimum overall performance. The IMT-Advanced systems shall support mobile speeds up to 350 km/h. It should provide optimal system performance for vehicular speeds less than 15 km/h, high performance between 15-120 km/h and graceful degradation of performance between 120-350 km/h to maintain session/call connectivity. Note that the requirements for handover are captured under latency requirements.

5.2.3 Technology complexity

The system and terminal complexity shall be minimized in order to stabilize the system and enable interoperability in earlier stage and decrease the cost of terminal and the RAN.

Therefore, the following shall be taken into account:

- The baseline requirements shall be met with mandatory features only.
- Minimum number of optional features may be considered only if they provide significant functional and performance improvements over baseline configuration.
- Support of multiple features, mandatory or optional, which are functionally similar and/or have similar impact on performance, shall be avoided.
- Reduce the number of necessary test cases, e.g. reduce the number of states of protocols, and minimize the number of procedures, appropriate parameter range and granularity.

5.2.4 Flexibility of radio interface

5.2.5 Implication on network interface

5.2.6 Cell Coverage

[Requirements that specify the area could be covered by a cell of the IMT-Advanced system.]

The IMT-Advanced systems shall provide significant enhancements relative to 3G systems with respect to coverage.

For cell sizes up to 5 km, the user throughput, spectral efficiency, and mobility support requirements should be met. For cell sizes up to 30 km, slight degradations in the achieved user throughput and more significant degradation in spectral efficiency are acceptable; however mobility performance targets should be met. Cell sizes up to 100 km, should not be precluded by the specifications. ~~A cell radius over 50km should be supported by proper configuration of the system parameters~~

5.2.7 5.2.7 Power efficiency

[The maximum transmission power allowed for achieving the performance requirements]

5.2.8 5.2.8 Spectrum compatibility

[Requirements that specify how the technology utilize spectrum and minimize interference to the adjacent spectrum. MIMO or Beam-Forming is a candidate technology for this requirement.]

5.2.9 Voice-over-IP

The VoIP capacity of IMT-Advanced systems shall be significantly higher than that of 3G systems. The VoIP capacity and call setup latency for the IMT-Advanced systems shall satisfy the following requirements:

Feature	Requirement	Comments

Number of VoIP Users/Sector (per MHz) Number of concurrent VoIP sessions/sector/MHz in a system fully loaded only with VoIP users	> 100 users/sector/FDD MHz > 50 users/sector/TDD MHz	System outage and FER shall be less than 3% and 3%, respectively. AMR shall be used as the default codec and 12.2 kbps with DTX enabled shall be considered as the default source rate.
VoIP (and PTT) call setup latency	< 1s	

5.2.10 Data services

The aggregate TCP capacity of IMT-Advanced systems shall be at least 2x relative to that of the 3G systems. The aggregate TCP capacity is defined as the sum of the TCP goodputs of all the users in a sector. It is measured above the TCP layer.

5.2.11 Enhanced location-based services (LBS)

The IMT-Advanced systems should provide support for enhanced LBS and should satisfy the following requirements:

Feature	Requirement	Comments
Location based services	Location Determination Latency < 1 s	To maintain session/call connectivity at high vehicular speeds
	Position Accuracy 50-250 m	Need to meet E911 Phase II Requirements

5.2.12 Enhanced multicast and broadcast service (MBS)

The performance of broadcast and multicast services in the IMT-Advanced systems should be evaluated independently of unicast services. The video capacity of the IMT-Advanced systems should be greater than 2x of that of the 3G systems assuming the entire physical resources are utilized for multicast and broadcast service.

Feature	Requirement	Comments
MBS channel switching time	< 1 s	
MBS video channel capacity	TBD	H.264/AVC shall be supported as the default video codec for evaluation purposes. AAC/AAC+ shall be supported as the default audio codec for evaluation purposes.

6 Conclusions

~~This Report provides useful information on technology issue which is required for evaluate the air interface(s) for IMT-Advanced.~~

This document provides a set of system requirements for IMT-Advanced radio access cellular systems. All IMT-Advanced compliant radio access technologies shall meet or exceed these requirements.

7 Terminology, abbreviations

Abbreviation	Description
AAS	Adaptive Antenna System
BS	Base Station
CALEA	Communications Assistance for Law Enforcement Act of 1994
CDF	Cumulative Distribution Function
DL	Downlink
FCH	Frame Control Header
FDD	Frequency Division Duplexing
FER	Frame Error Rate
FTP	File Transfer Protocol
L2/L3	Layer 2/Layer 3
LAN	Local Area Network
LBS	Location Based Services
MAC	Medium Access Control
MBS	Multicast and Broadcast Service
MG	Major Group
MIMO	Multiple-Input Multiple-Output
MS	Mobile Station
OFDMA	Orthogonal Frequency Division Multiple Access
PAN	Personal Area Network
PHY	Physical Layer
PoC	Push over Cellular
PUSC	Partial Use of Sub-Carriers
QoS	Quality of Service
RRM	Radio Resource Management
RS	Relay Station
TCP	Transport Control Protocol
TDD	Time Division Duplexing
UL	Uplink

VoIP	Voice over Internet Protocol
VPN	Virtual Private Network
WAN	Wide Area Network

Appendix 1

8 Overview of major new technologies (informative)

8.1 Spectrum and deployment

[Editor Note: Technologies that can improve~~ing~~ spectrum efficiency, flexibility and sharing possibility could be included in this section.]

8.2 Radio Access Interface and Network

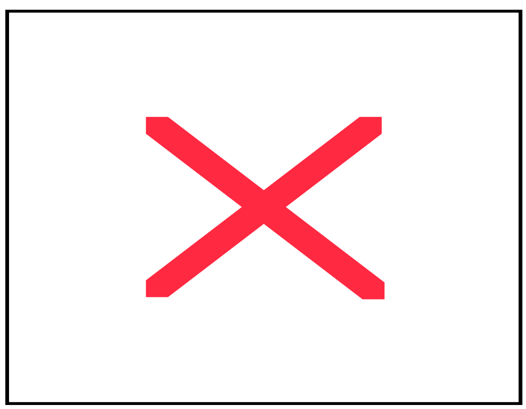
[Editor Note: New radio access technologies, such as soft-defined radio, short range radio and new multiple access method etc, could be included in this section. The innovations of network deployment, e.g. wireless relay enhanced cellular, can also be included in this section]

8.2.1 Network topology

8.2.1.1 Single-hop mode

The information is transmitted between radio access point (e.g. base-station) and mobile stations (e.g. user terminals) directly in a single hop. An example of network topology in this case is shown in the following figure~~)~~.

~~Working~~ Operation mode of radio access network – Single Hop Mode

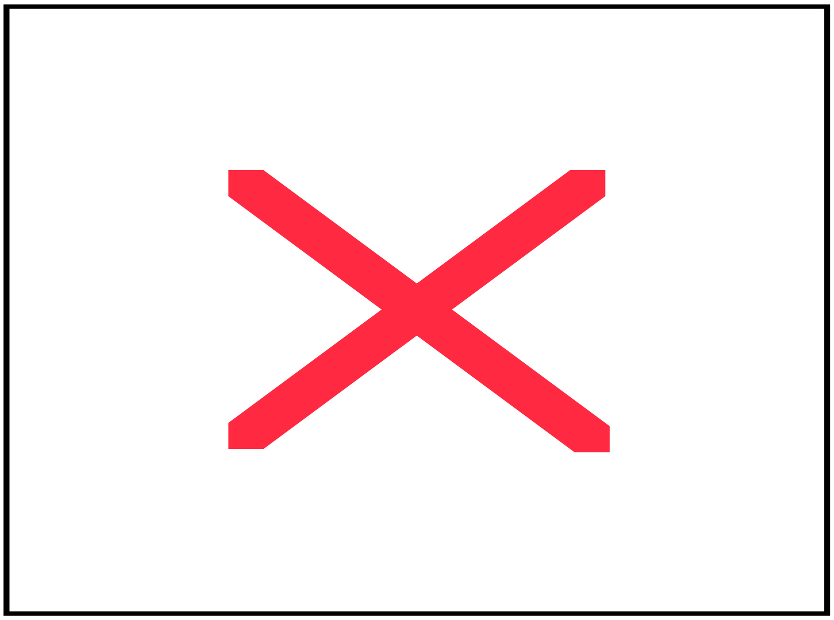


8.2.1.2 Multi-hop mode

The direct communications between BSs and the data transportation through multihop across BSs should be considered.

The information is transmitted between radio access point to mobile stations in more than one hop. The intermediate points between access point and destination are relay nodes that regenerate and re-transmit radio signals. The topology of multi-hop mode is shown in the following figure.

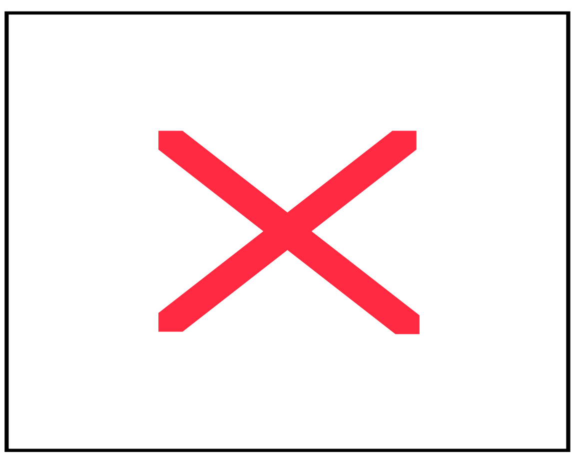
~~Working~~ Operation mode of radio access network – Multi Hop Mode



8.2.1.3 Mesh mode

This mode is similar to multi-hop mode. However, in this mode, relay nodes are supposed to have connections between each of them, if physically possible. Routing algorithms between relay nodes are necessary in this mode. An example of network topology in this case is shown in the following figure.

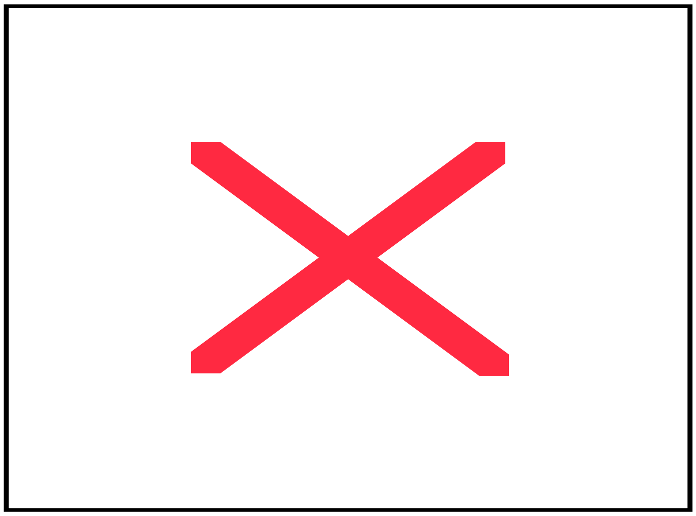
~~Working~~ Operation mode of radio access network – Mesh Mode



8.2.1.4 Peer-to-peer mode

In this mode, mobile stations are connected directly or through relay nodes, but no radio access point are explicit in their connections. An example of network topology in this case is shown in the following figure.

~~Working~~ Operation mode of radio access network – Peer-to-Peer Mode



8.2.2 Duplexing schemes

8.2.2.1 FDD

Conventional frequency division duplex (FDD) operation allocates equal-size paired spectrum for uplink and downlink. It is expected that the future IMT-Advanced systems would require higher data rate and throughput mainly in downlink to support ultra high-speed asymmetric services, e.g. large-size file downloading (similar to broadband internet access) and high-quality video broadcasting (similar to digital TV). These asymmetric services encourage an asymmetric spectrum allocation for IMT-Advanced deployment.

8.2.2.2 TDD

Conventional time division duplex (TDD) operation can efficiently support asymmetric transmission~~ very well~~. Flexibility is available with respect to the degree of traffic asymmetry, depending on the co-channel and adjacent channel interference conditions. The spectrum efficiency of the arrangement is less dependent on the actual network traffic asymmetry since TDD can vary the degree of asymmetry within a specified range.

8.2.2.3 Half duplex FDD (H-FDD)

~~TBD~~

The H-FDD is a less complex implementation of FDD where the device DL and UL transmissions are not overlapping, eliminating the need for RF duplexer and allowing reuse of TX and RX building blocks (e.g., FFT module). The H-FDD terminals can have lower power consumption and smaller form factor compared to that of FDD devices. Note that the BS is operating in FDD mode; that is DL transmissions and UL reception of the BS occurs at the same time.

Therefore, the BS scheduler should take into consideration that the H-FDD MS cannot receive and transmit at the same time. Also the BS should allow a gap between any DL to UL and UL to DL switching for a particular H-FDD MS.

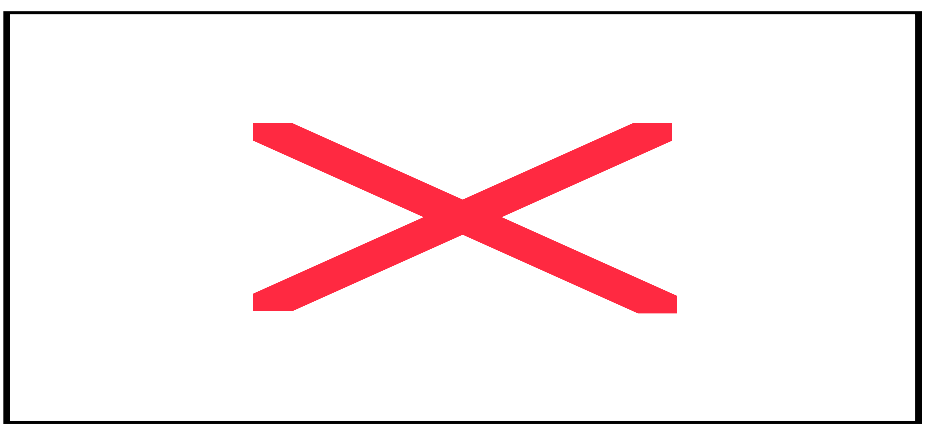
8.2.3 Multiple-Access technologies

8.2.3.1 Single-carrier transmission

8.2.3.2 Multi-carrier transmission

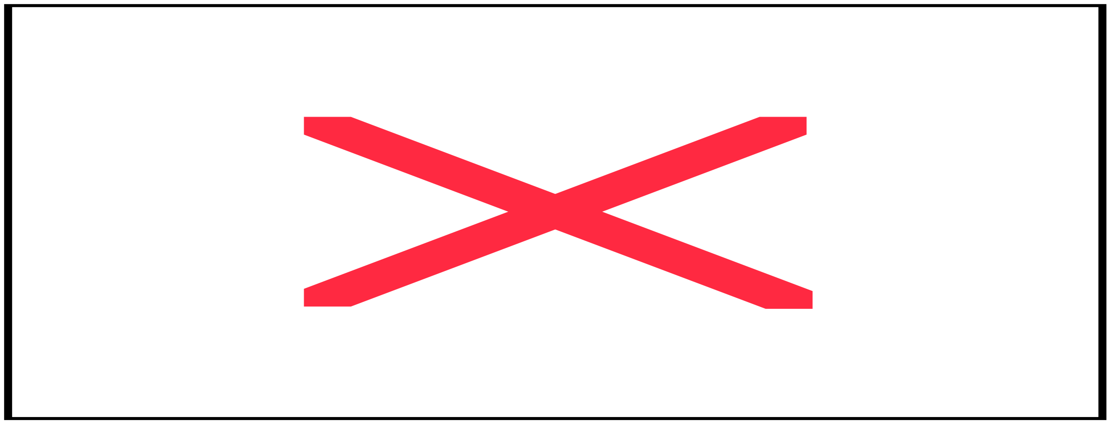
8.2.3.2.1 OFDMA

Orthogonal Frequency Division Multiplexing (OFDM) is a multiplexing technique that subdivides the bandwidth into multiple frequency sub-carriers as shown in the following figure. In an OFDM system, the input data stream is divided into several parallel sub-streams of reduced data rate (thus increased symbol duration) and each sub-stream is modulated and transmitted on a separate orthogonal sub-carrier. The increased symbol duration improves the robustness of OFDM to delay spread. Furthermore, the introduction of the cyclic prefix (CP) can completely eliminate Inter-Symbol Interference (ISI) as long as the CP duration is longer than the channel delay spread.



Basic Architecture of an OFDM System

The CP is typically a repetition of the last samples of data portion of the block that is appended to the beginning of the data payload as shown in the following figure. The CP prevents inter-block interference and makes the channel appear circular and permits low-complexity frequency domain equalization. A perceived drawback of CP is that it introduces overhead, which effectively reduces bandwidth efficiency. While the CP does reduce bandwidth efficiency somewhat, the impact of the CP is similar to the “roll-off factor” in raised-cosine filtered single-carrier systems. Since OFDM signal power spectrum has a very sharp fall of at the edge of channel, larger fraction of the allocated channel bandwidth can be utilized for data transmission, which helps to moderate the loss in efficiency due to the cyclic prefix.

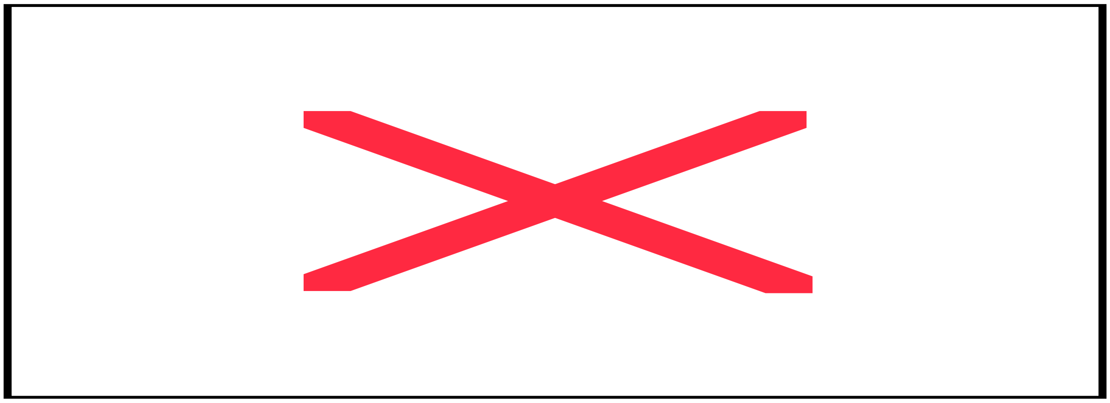


Insertion of Cyclic Prefix (CP)

OFDM exploits the frequency diversity of the multipath channel by coding and interleaving the information across the sub-carriers prior to transmissions. OFDM modulation can be realized with efficient Inverse Fast Fourier Transform (IFFT), which enables a large number of sub-carriers with low complexity. In an OFDM system, resources are available in the time domain by means of OFDM symbols and in the frequency domain by means of sub-carriers. The time and frequency resources can be organized into sub-channels for allocation to individual users. Orthogonal Frequency Division Multiple Access (OFDMA) is a multiple-access/multiplexing scheme that provides multiplexing operation of data streams from multiple users onto the downlink sub-channels and uplink multiple access by means of uplink sub-channels.

The OFDMA symbol structure consists of three types of sub-carriers as shown in the following figure:

- Data sub-carriers for data transmission
- Pilot sub-carriers for estimation and synchronization purposes
- Null sub-carriers for no transmission; used for guard band and DC sub-carriers



OFDMA Sub-Carrier Structure

Active (data and pilot) sub-carriers are grouped into subsets of sub-carriers called sub-channels. Scalable OFDMA supports a wide range of bandwidths to flexibly address the need for various spectrum allocation and usage model requirements. The scalability is supported by adjusting the FFT size while fixing the sub-carrier spacing and thereby OFDM useful symbol duration regardless of the operating bandwidth.

8.2.3.2.2 Multi-carrier CDMA

8.2.4 Multiple-Antenna technologies

8.2.4.1 MIMO ~~(MTMR)~~

8.2.4.1.1 Single-User MIMO (SU-MIMO)

8.2.4.1.2 Multi-User MIMO (MU-MIMO)

8.2.4.2 Beam forming (Smart Antenna)

8.2.5 Channel Coding

8.2.5.1 Turbo codes

Double binary tail-biting turbo codes can be regarded as one choice of improved turbo codes.

For the component encoder of the improved turbo codes, the Double Binary Circular Recursive Systematic Convolutional codes shall substitute the original Binary Recursive Systematic Convolutional Codes, which leads to the improvement of the link performance. Compared to the original binary turbo codes, the double binary turbo codes can eliminate the error floor, decrease the performance gap between the optimal algorithm and the approximate algorithm, and enhance the performance of high code rate.

Since the tail bits of ~~UTRA~~ Turbo coding reduce the throughput, tail-biting trellis termination can be considered to improve the transmission efficiency, and then the tail bits can be removed.

To obtain variable code rate and extend the application fields, the combination of rate matching and the improved turbo codes should be considered as a complement of turbo coding.

The improved turbo codes should have the capability of supporting iterative redundancy HARQ (IR-HARQ).

8.2.5.2 Low density parity check codes (LDPC)

LDPC coding can be considered an alternative channel coding scheme in that it has such benefits as low complexity, large decoder throughput, low latency, and high coding performance.

A special type of LDPC codes, namely structured-LDPC codes, can achieve very efficient hardware architecture and routing. The code rate of LDPC codes is flexible by using different base matrices or by shortening or puncturing base matrices. The code size can be flexible by modifying one base matrix. As a typical choice, with single uniform base matrix and single uniform hardware structure, any code rate and any code size can be supported.

The LDPC codes should have the capability of supporting IR-HARQ.

For irregular LDPC codes, the protection abilities vary differently from the nodes' degrees, and the differential protection ability of different degrees should be considered (e. g. HARQ).

The LDPC coded modulation possibly shall be exploited to improve the link performance.

8.2.6 Mobility management and RRM

8.2.6.1 Centralized RRM

8.2.6.2 Distributed RRM

8.2.6.3 Inter-RAT spectrum sharing

8.2.6.4 Inter-RAT mobility management

8.3 Mobile user interface

[Editor Note: ~~This section include~~This section includes new technologies that can improve user experience when using mobile communication service.]

8.3.1 Mobile user terminal design

8.3.2 New innovative network to humane interfaces

8.3.3 Human-free interface

RF micro-electro-mechanical systems (MEMS)

8.3.4 Reconfigurable networks

Appendix 2

9 The application of MIMO technology in IMT-Advanced systems (informative)

In the IMT-Advanced systems, MIMO technology mainly is introduced in the region the capacity already has approached the limit, or hot spot area.

9.1 The multi-antenna system application scenario

~~Better~~ Improved performance can be achieved in the following scenarios by using MIMO technology.

Scenario A (suburban macro): The wireless downlink channel, the base station position is high, the wireless signal scattering spots around the mobile terminations are rich. Then, looking from the terminal antenna, the wireless channel relevance of the base station with many transmit antenna is high, but looking from the base station antenna, the wireless channel relevance of the terminal with many receiving antenna is weak, namely low transmit diversity, high receive diversity scenario.

Scenario B (urban macro): The uplink wireless channel of scenario A, high transmit diversity, low receive diversity scenario.

Scenario C (urban micro): The wireless channel relevance of transmit, receiving antenna in uplink, downlink channel is medium, namely the medium transmit diversity, the medium receive diversity scenario.

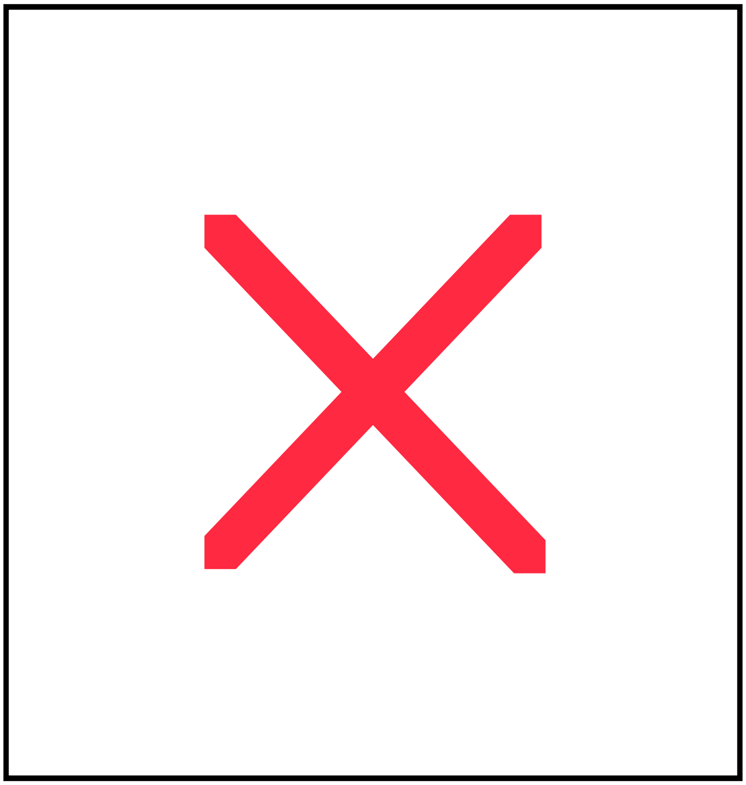
Scenario D (line of sight-LOS): Because of the existence of the LOS component signal, the relevance between transmit and receive antennas is very strong, namely the low transmit diversity, the low receive diversity scenario (MIMO techniques will not be effective in this scenario).

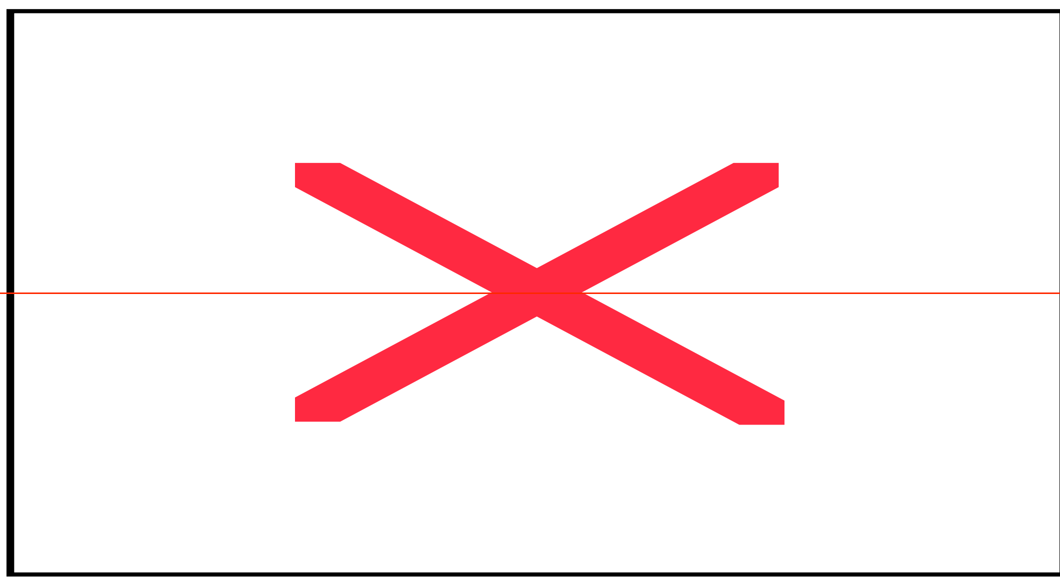
Performance lost may be suffered in the following scenario: low SNR area and high mobile scenario.

~~Because~~Since MIMO ~~technical~~techniques may need channel information feedback between receiving and transmitting stations, based on present feedback mechanism, when ~~UE~~MS ~~makes~~moves at ~~the~~ high speeds ~~migration~~ (e.g. velocity > 50km/h), ~~The feedback speed is unable to support the variation rate of measure information; These measure information including the scope and phase information in closed loop diversity pattern, as well as feedback link quality information~~.

In addition, the micro honeycomb environment with rich multi-diameter condition can maximize the MIMO antenna gain, therefore the multi-antenna technology more suits for the micro honeycomb scenario such as the crowded city, the city, the room and so on. One kind of intelligent MIMO system based on the using boundary and user demand is shown in Figure 1.

The application of ~~smart~~ MIMO in different scenarios (courtesy of 3GPP2 C30-20060911-035)



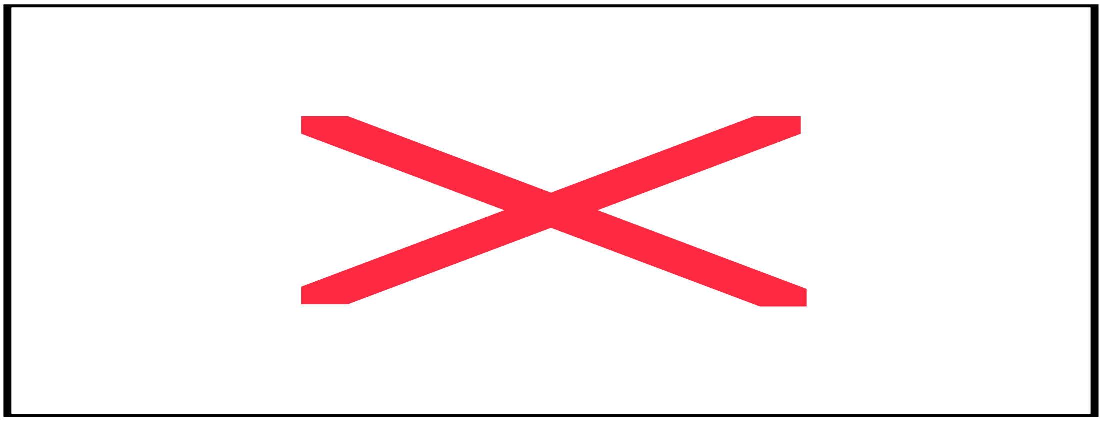


10 The impact of MIMO~~'s impact~~ on mobility

~~After introducing MIMO, the wireless environment of cell has improved, and the carry frequency quality of UE has obtained quite large gain, and the number of hand-over in~~

~~mobility management has decreased. Because every pair of antennas have been configured a dedicated pilot channel, not a common pilot channel as in SISO. The condition of hand-over synthetically considers multi-pilot channel quality according to some algorithm~~.

Considering the following network configuration, there are MIMO cells and non-MIMO cells in the ~~neighbour~~neighbor ~~NodeB~~BS and in different frequency within a ~~NodeB~~BS. Because of the mobility of ~~UE~~ MS and payload, that may lead to the following scenario.



- ~~UE~~MSs ~~work~~ operate at the F1 frequency in ~~NodeB~~BS3, and move towards ~~NodeB~~BS1 (Figure 2 A)
  - If the current ~~UE~~MS is MIMO ~~UE~~MS, when ~~UE~~MS moves from ~~NodeB~~BS3 towards ~~NodeB~~BS1, system should touch off the soft hand-over. For service channel, network can select a best cell according to channel quality, make it as service cell.
  - If the current ~~UE~~MS is MIMO ~~UE~~MS, but works at the frequency F2 in ~~NodeB~~BS3, when moving towards Node B, there are two different strategies: one is to make soft hand-over in same frequency, and the other is to make hard hand-over in different frequency, that makes the ~~UE~~MS hand off the frequency which supports MIMO. The former can make use of the benefit which is leaded by soft hand-over, and the disadvantage is the ~~UE~~MS still works on the non-MIMO cell. The latter avoids the disadvantage, but that leads the complexity of hand-over increases.
  - If the current ~~UE~~MS is MIMO ~~UE~~MS, whether working at F1 or F2, soft hand-over should be the optimum choice.
- When the above example occurs in one ~~NodeB~~BS, the strategy should be the same as the different ~~NodeB~~BS. The only difference is the hand-over is the softer hand-over.

- If MIMO UEMS moves into a non-MIMO cell(C), the network side can balance between to hold the MIMO service and to ensure UEMS interference to system at the same frequency is minimum. That is to say, network can configure higher threshold which is used to touch off moving towards non-MIMO, that ensures the largest delay of MIMO service. We can also use the same threshold as the normal hand-over, to ensure MIMO UE MSs can not produce too large payload to network.
- At different frequency in one NodeBBS, we also solve the payload balance through blind hand-over in one NodeBBS (D). The blind hand-over in one NodeBBS can be touched by the change of channel type. This can place the MIMO UE MSs and non-MIMO UE MSs in MIMO cells and non-MIMO cells as possible to ensure the performance of MIMO UEMS.

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