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Challenges in 5G testing & evaluation

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Challenges posed by new technologies to testing & evaluation

New technologies to testing & evaluation:

- The proposed new network architecture and emergence of various types of transmission technology will pose new challenges to 5G air interface technology standardization , program design and simulation.
- For physical layer transmission technology , 5G will introduce new waveform & non orthogonal multiple access at the physical layer to achieve the required traffic latency in air interface.

New technologies to testing & evaluation:

- To explore spatial freedom & improve the network throughput, 5G will introduce massive MIMO technology. In simulation evaluation system , massive MIMO & MU-MIMO technology will greatly increase computational interference complexity.
- The new channel propagation model will be introduced based on high frequency band transmission technology, D2D technology & massive MIMO technology.

New technologies to testing & evaluation:

- Need to design scheduling algorithm for heterogeneous computing resources, accurately estimate the consumed time of heterogeneous computing & interface data transmission and meanwhile design the synchronized mechanism for computing tasks to make full use of heterogeneous computing platform.

Elements of Testing & Evaluation

Four elements of testing & evaluation:

There are four elements of testing and evaluation requirements :

- Realness
- Comprehensiveness
- Rapidly
- flexibility

Realness

Realness :

- In the 5G testing & evaluation, the requirement for realness is reflected in 5G wireless channel model, verification methods , user experience and other aspects.
- From the point of network topology, various link types in 5G will co-exist in a same region, extending from traditional macrocell and microcell to picocell , femtocell and support V2V, M2M network architecture.

Realness :

- Two way mobility of D2D/V2V will introduce doppler model & massively intensive scattering exists in both transmitter and receiver & the stationary cycle is short , all of which need to be considered in the channel model.
- Wide range propagation scenarios and diversified network topologies emerge in 5G research , which pose challenges to the channel model.

Challenges :

- Unique transmission characteristics of radio waves in higher frequency & bandwidth.
- Plane wave propagation model assumption is no longer applicable and scattered clusters non stationary feature is reflected not only in the time axis , but it is also changing along the array.

challenges ：

- Software simulation assumes that the hardware design can perfectly realize the software algorithms and thus we cannot introduce the impact of hardware conditions on the communication systems.
- In reality, algorithm design is often restricted by the hardware conditions , and the software algorithms are often greatly reduced , when realized in hardware.

Realness :

- The algorithms at the front of transmitter and receiver have to consider power , the impact on other hardware components and many other factors.
- Verification of the tested technology or prototype equipment in real scenario through “algorithm realization “ ----> data acquisition ----> system optimization ----> outfield verification , providing basis for standardization.

Comprehensiveness

Comprehensiveness :

Demand for testing & evaluating comprehensiveness mainly involves two aspects :

- It lies in the comprehensive support for the evaluation of 5G performance indicators.
- It lies in the comprehensive support for the diversification of candidate technologies.

Comprehensiveness ：

5G evaluation indicators system will include the objective indicators like :

- Transmission
- Network
- User experience indicators

Comprehensiveness :

5G candidate technologies can be divided into two categories :

- Air interface technology
- Network technology

Rapidly

Rapidly :

- In order to meet the KPI's in 5G, the computing performance of the simulation system must grow by more than 1000 times before meeting the requirements of the timely evaluation of simulation task.

Rapidly :

- With such rapid growth in computational performance , a systematic and brand new design & realization are needed in simulation system's hardware platform , software platform and simulation application.
- For the simulation system, the key problem is how to complete concurrent design & coding implementation on the new & powerful hardware platform with powerful computational capabilities.

Flexibility

Flexibility :

- Affected by flexible network architecture, network resource virtualization management , parallel computing needs & other factors , simulation & validation system needs to have enough flexibility.
- Architecture design , module design and interface design have the characteristics of coupling , modularization , interface expansion , easy integration and so on.

Evolution of testing technology

Evolution ：

- Testing & evaluation are indispensable links of technology and product inspection.
- Every new technology requires strict testing and evaluating process.

Importance of testing technology :

- Testing is measurement, inspection & test.
- Testing is an important step for checking the entire product's quality and it proves important to improve product quality.
- Any new technology or product must be fully tested and evaluated.
- Testing technology needs to run through the entire process , from pre-design stage to design stage to production completion stage.

Testing technology :

- Testing technology plays an important role in all stages of a product or technology from prototype to standardization.
- The testing & measurement solutions at each stage are important guarantees for successful application of new technologies & products.

Development of testing instruments :

- Instruments are combination of various sciences & technologies with many varieties and wide applications.
- To ensure more reliable performance & more powerful integrated functions, the mature testing equipment & advanced & reliable testing methods are needed. Powerful testing instruments are indispensable to the stable & reliable running of new wireless communication equipment.

Development of testing instruments :

The development of test equipments can be divided into three eras :

- Instrument 1.0 era
- Instrument 2.0 era
- Instrument 3.0 era

Development of testing instruments

Instrument 1.0 era ：

- Microprocessors have improved performance & automation degree of instruments , facilitating automatic range conversion , automatic zero adjustment , trigger level automatic adjustment, automatic calibration , self- diagnosis and many other functions.

Instrument 2.0 era :

- With development of computers , test instruments began to transform.
- Use of flexible instruments based on software design.
- In this, the users can redevelop the instruments according to their own needs.

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Instrument 2.0 era :

The combination of multiple techniques helped to create a number of high performance testing systems that increased the flexibility of testing and brought higher performance and lower cost.

- Bus technology
- Software defined radio technology
- Modular instrument technology
- Hybrid test system

Bus technology :

- Through the test bus, tha data communication between different units and modules in the testing instruments are realized.
- These standards allows testing engineers to assemble a variety of automatic measurement systems with powerful functions by very convenient means.
- Representative bus technologies includes VMEbus extensions for instrumentation (VXI) , peripheral component interconnect (PCI), peripheral component interconnect express (PCIe), LAN extension for instrumentation (LXI).

Software defined radio technology :

- It is the most representative technology of instrument 2.0 era.
- The software radio is to take hardware as the basic platform of wireless communications and implement the maximal functions of wireless communications and personal communications with software.
- The basic idea is to let all the tactile radios in use be based on same hardware platform, install different software to form different types of radio , complete functions of different natures , and get the software programmable capability.

Software defined radio technology :

- The key idea of software radio is to construct a standardized, modular universal hardware platform to realize various functions by software, and to make the broadband A/D and D/A convert to IF, near the RF side of the antenna , and strive to carry out the digital processing from IF.
- Software radio requires a very high speed of hardware and software processing.

Modular instrument technology :

- High speed communications test instruments featuring modular, software and integration continue to spring up, which complement and get closely integrated with traditional methods expanding the applications continuously and forming a technical highlight in the communication centred application field.
- VXI was the earliest bus which introduced the concept of modular instrument.

Modular instrument technology :

- Modular instruments integrated with computers and suitable for PCI and PXI platforms are highly flexible plug-in computer boards.
- Modular instruments are an important part of SDR technology.
- With the aid of modular instruments , engineers can choose different kinds of modular instruments according to their measurement needs and set up a test system.

Hybrid test system :

- The hybrid systems composed of different bus technologies and instruments are gradually appearing in the testing field.
- In a hybrid test system, different components of multiple automated test platforms are integrated in a system including PCI, PXI, GPIB, VXI, USB, LAN and other different buses.

Instrument 3.0 era :

- It reflects the characteristics of openness, union and service.
- Cloud testing , software and hardware joint multi user system simulation test is a series of applications confirming the characteristics of instrument 3.0 technology.

Development trend of testing technology

Co-existence of new & traditional test equipment :

- Users can integrate test into the design process in a faster and more flexible way, shorten the development time and improve the test efficiency.

Leading trend

The leading trend of many-core / parallel technology & FPGA real time technology :

Many core parallel technology :

- The number of cores in a server processor is increasing drastically to more than 10 and the processor is developing towards many core.
- The emergence and development of multi-core/many processors is a choice of development of semiconductor industry.
- The development of multi-core technology will promote the development of test industry.

Real time FPGA technology :

- FPGA can realize the advantages of customized hardware tools through the flexible software system.
- FPGA is suitable for uninterrupted filtering, modulation /demodulation , encryption or other data processing.
- To ensure the inherent parallelism of data.

Real time FPGA technology :

- It is defined by software first and then downloaded to a FPGA chip for an actual execution.
- As design and testing requirements become higher and higher , the FPGA technology is introduced into the FPGA based customized instruments.

Real time FPGA technology :

- For 5G wireless communications , FPGA will be needed to ensure that the response is real time and the inflow and outflow speed of the data are high in real time system simulation and high speed memory test applications.
- R-series data collection and FlexRIO products family provided by NI have integrated the high performance FPGA into readily available I/O broadcard for users to customize and repeat configurations according to the applications.

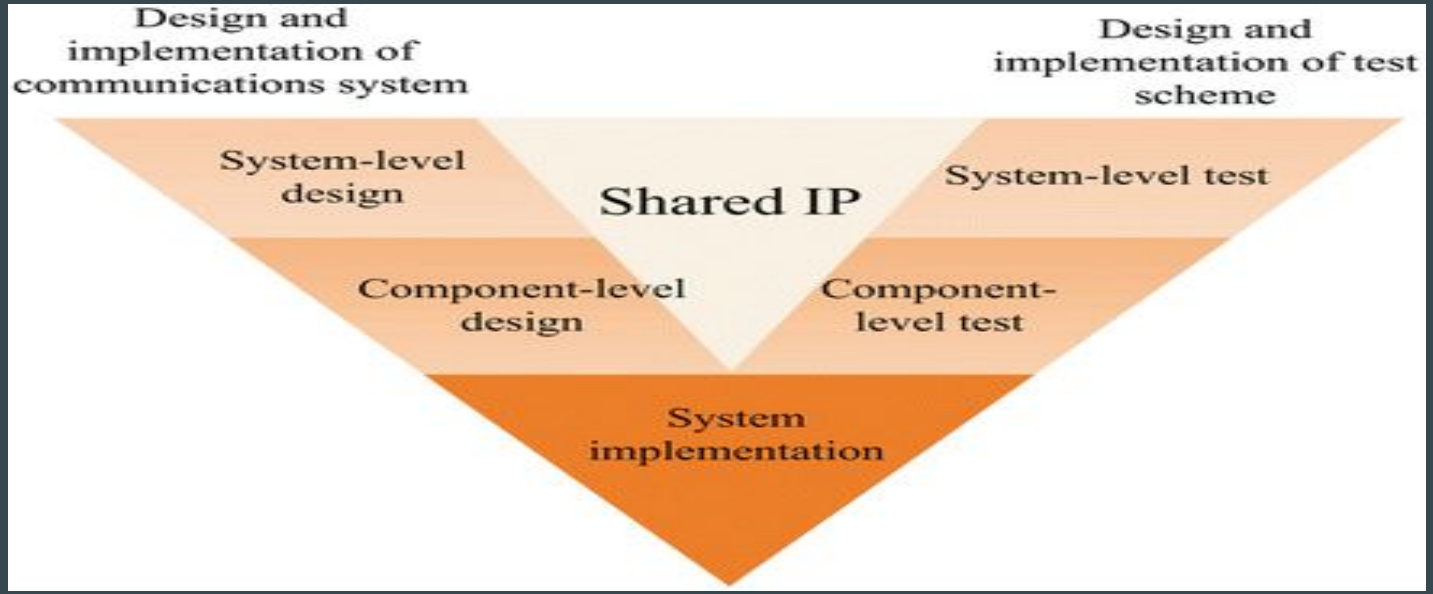
Test ecosystem becomes the trend

FPGA based IP to the PIN technology

- Adopting “system-level approach , integrating the concepts of design and test, and expanding software architecture to FPGA “ is one of the effective means to balance the development and improve the efficiency of communications testing .

FPGA based IP to the PIN technology

- The specific implementation of IP to the pin technology can be expressed as a “V” graph.



Heterogeneous computing architecture

Heterogeneous computing architecture supporting parallel testing and massive signal processing :

- The heterogeneous computing architecture is a system for assigning data processing & program execution tasks among different computing nodes, so that each node can handle the most appropriate test & calculation task.

Heterogeneous computing architecture

- Along with the rapid development of high bandwidth and high data rate of 5G mobile communications, the combination of heterogeneous computing architecture and the multi-core parallel programming technology will be indispensable main technology with which 5G test is able to deal with massive data processing and improve the parallel testing.

Challenges of Testing technology

Challenges of multi-function & high performance :

- The development of digital simulation technology and the increase of the frequency band of RF test are urging the development of testing technology.
- WLAN standards are applied in BW< 100 Mhz , so it doesn't need special methods of testing technology.

Challenges of multi-channel

- As per information theory, the more the number of antennas are , the more obvious increase in the spectrum efficiency and reliability.
- When the number of transmitting & receiving antennas is large , the MIMO channel capacity will have a close to linear increase along with the minimum number of transmitting & receiving antennas.

Challenges of multi-channel

- Requirements need a large number of OTA (over the air) tests for support.
- Number of cooperative antenna at side of 5G BS should not be less than 128.
- The number of antennas on this massive MIMO technology has risen to hundreds, larger than traditional.

Challenges of high throughput

5G will promote service ability in three dimensions at the same time :

- Improve the utilization rate of resources by more than 10 times as compared to 4G.
- Increase the system throughput rate by about 25 times by introducing UDN's & deeper intelligence capabilities.
- Explore new frequency resources (such as high frequency band, millimeter wave & visible light etc).

Challenges of high throughput

- Massive data has put forward new requirements on the RF test in both the method and the equipment.
- Keithley's new generation MIMO test platform makes it simpler and cheaper to increase new signal standards and MIMO options.

Chapter 3

Channel Measurement and modelling

Channel measurement & modelling

- The wireless channel model is numerical description of physical propagation environments.
- It provides an effective and simple means to approximately express the channel characteristics of the wireless transmission.

Requirements for 5G wireless channel model :

- Applications and new technologies for 5G communications poses many challenges in 5G wireless channel model.
- 5G channel model should support wide range propagation scenarios, higher frequency and larger bandwidth

5G channel model

5G channel model should support :

- Wide range propagation scenarios and diverse network topologies.
- Higher communications frequencies and larger bandwidth.
- Massive MIMO
- Spatial consistency and dual mobility
- High mobility

Wider range propagation scenarios

- 5G channel model should support mobile to mobile links and networks.
- Network topology should not support only cellular networks but also communications of D2D , M2M and V2V.

Higher communications frequency

- 5G may operate in frequency range from 350 Mhz to 100 Ghz.
- In 3GPP-HF channel model , if the BW of a channel is beyond c/D , then such BW referred to as big BW.
- Propagation in HF band will undergo path loss due to shorter wavelength.

Massive MIMO

- Planar wavefront assumption for conventional MIMO channels is no longer applicable and should be replaced by spherical wavefront assumption.
- Channel model must provide 3D angle information.

Spatial consistency & dual mobility

- 5G channel model should support spatial consistency.
- With co-existence and density increase of links , and with application of D2D/ V2V , to support spatial consistency become especially important for wireless channel models.

Channel modelling method

Channel modelling method

- In Deterministic channel model, there is prediction of characteristics at every point in space.
- Stochastic channel modelling is a kind of method to obtain huge measurement data set.
- GSCM is known as geometric based stochastic channel model.

Channel modelling method

- Channel parameters are divided into path loss , large scale parameters such as shadowing , delay spread , angular speed etc
- Small scale parameters such as delay , angle of arrival & departure etc , which jointly reflect the channel fading characteristics .
- Large scale parameters can be regarded as a statistical average in a channel segment within which LSP or probability distribution of LSP do not change significantly.

Channel modelling method

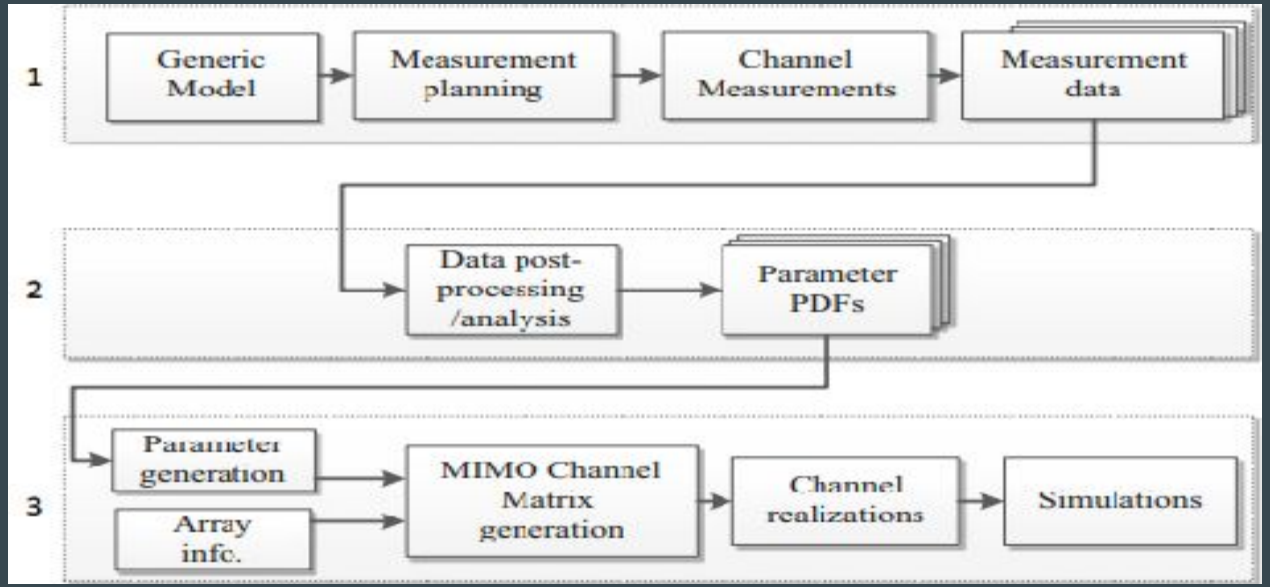
- Close-in reference short model
- ABG (Alpha , beta , gamma) model

Measurement-based GSCM

- The GSCM modelling method separates antennas and propagation channel.
- The clusters and rays in channel are parameterized by path loss, shadowing & other parameters in large scale & small scale.

Stage 1

Preparation & measurement



Stage 2

Post processing of the measured data

- Different analysis methods are applied depending on the required parameters.
- High resolution parameter estimation algorithms are required.

Stage 3

Generation of simulation model

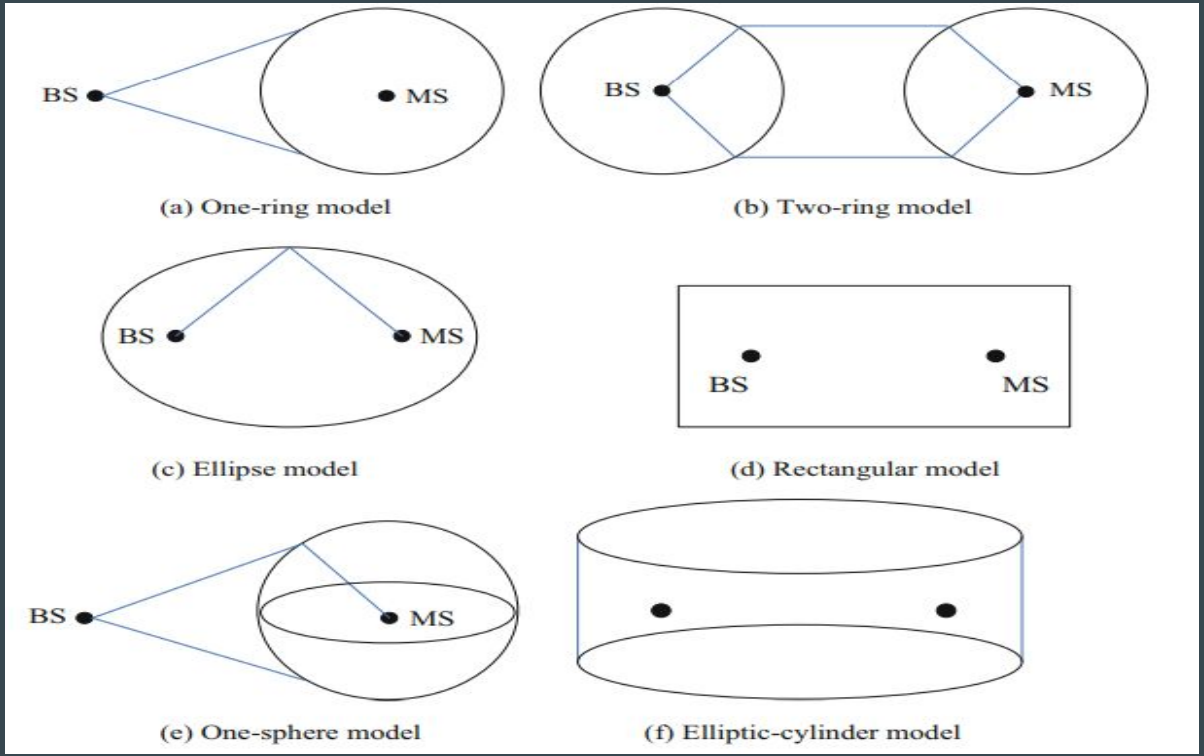
- Clusters and ray parameters are generated according to their PDF's and statistical parameters.
- Measurement based GSCM modelling method has been widely recognized & used.

Regular shape GSCM

Regular shape GSCM

- The characteristics of the propagation channel are described according to the geometric relationships among the transmitter, receiver & scatterers.

Regular shape GSCM



Regular shape GSCM

- The basic shapes of 2D distribution of scatterers mainly include : one ring, eclipse and rectangular.
- The basic shapes of 3D distribution of scatterers include : one sphere , two spheres etc.
- The geometric model in practical application can be combination of these basic shapes and it is also possible to add new geometric shapes.

CSCM

CSCM

- It describes the MIMO channel by the correlation matrix of antennas.
- The existing CSCM model mainly includes :
- IID
- KBSM
- VCR
- Weichselberger channel model

Extended SV & Ray tracing model

Extended SV model

- It can only describe the delay information of the channel and its resolution is higher than 10 ns subjected to the sounding equipments.

Ray tracing based model

Ray tracing based model

- The propagation prediction of EM wave can be solved by analytical method based on electro-magnetic theory or by electromagnetics.
- Ray tracing method is based on relatively simple geometrical optics and uniform theory of diffraction.

Basic principle

- To use rays to simulate the electro-magnetic wave propagation process , such as direct ray , diffraction , reflection & scattering.
- Calculation of the field strength of rays and path tracking of rays are two main aspects of Ray tracing technique.
- RT treats the propagation of EM wave by means of rays propagation.

Channel measurement

Channel measurement

- It is also known as channel sounding .
- It is a direct and most important mean to obtain channel information & understand the characteristics of the channel.
- By exploiting the received signals , multiple propagation paths can be identified.

Channel measurement methods

- Channel measurement methods can be divided into SISO, MIMO, SIMO.
- MIMO method simultaneously measures multiple channels in parallel.
- SISO only needs one RF chains at transmitter and receiver respectively.
- SIMO is a compromise between SISO & MIMO.

Channel measurement activities

With the on going progress in 5G R&D, channel measurements are divided into three categories :

- Measurement of massive MIMO
- Measurement of D2D/V2V/HSR
- Measurement of mmWave band

Massive MIMO measurement

- Massive MIMO is a promising technology for 5G communication.
- For measurement, BS was placed indoors and configured with a polarized uniform cylindrical array with 128 ports.
- Measurements were carried out outdoor with a larger space using two systems at in the same position and results were compared.

Massive MIMO measurement

- Massive MIMO

Measurement of D2D, V2V & HSR

Measurement of D2D, V2V & HSR

- D2D/V2V and high speed rail (HSR) communications are important for 5G wireless communications.
- MIMO technology will be widely used in vehicle communication systems because it can improve the system capacity & guarantee reliable data transmission.
- Measurements were carried out during the day and night time in order to observe the effects of pedestrians on the channel.

Measurement of D2D, V2V & HSR

Three scenarios were designed as follows :

- 1st scenario was at crossroads , where the transmitter standed statically near an intersection , while the receiver moved in perpendicular direction of intersection with a speed of 30-40 km/h.
- 2nd scenario is at expressway with two lanes , where the transmitting car was blocked in one lane & the receiving car approached to the transmitter in another lane with speed of 70 kmph.

Measurement of D2D, V2V & HSR

- 3rd scenario is two cars were derived at speed of 110 kmph in one lane of a two lane highway where both cars were obstructed by a tall van.

Measurement of D2D, V2V & HSR

In the same sounding system was adopted to measure in more scenarios including following situations :

- Road crossing
- General LOS obstruction
- Ramp merging
- Traffic congestion
- In tunnel
- On bridge

Measurement of mmWave band

- The measurement activities were designed and targeted to a specific measurement environment, but the similar equipments and procedures were used.
- Directional antennas was installed on a 3G rotating tripod.

Channel measurement

Channel data processing

- In channel sounding, the measurement data , or the received signals are superposition of altered versions of the transmit signal passing through multiple paths with different delays, gains and directions.

Path parameters extraction

- There are mainly two categories of commonly used channel parameters extraction algorithms i.e subspace - based methods and maximum likelihood methods.
- Within first category are MUSIC (Multiple signal classification) algorithm , ESPRIT (estimation of signal parameter via rotational invariance techniques) algorithm.

EM algorithm

- Basing on signal model, one can write the probability density function (PDF) of the measurement data in terms of signal parameters.
- EM algorithm can effectively estimate parameters by iteratively carrying out the E step & M step

SAGE algorithm

- It is developed based on the classical EM algorithm.
- In M step , it divides all parameters of one path into several sets and updates only one set of parameters at a time while keeping other sets of parameters fixed.
- The process continues till all the parameters of one path are updated.

FD-SAGE algorithm

- The SAGE algorithm mentioned is applicable for channel sounding using time domain PN excitation signal.
- In some channel sounding , frequency excitation signal is commonly used , such as broadband multi-carrier excitation or VNA based single frequency stepping excitation.
- Frequency domain sage algorithm is developed for parameter execution .

DMC and its estimation

- The Signal emitting from transmit antenna and arriving the receiving antenna is composed of a LOS components, specular components and dense multipath components.
- Each SC corresponds to a discrete and strong propagation path formed by an independent scatterer reflecting EM waves.

Mobile channel estimation and tracking

- To model the dynamic channel accurately , it is required to estimate and track the number of paths & multipath parameters.

Automatic clustering algorithm

- It has been found that the channel MPC tend to appear in clusters i.e in groups of MPC's with similar parameters.

Software simulation

Software simulation

- When compatibility and interoperability with other systems are considered , its network structure and networking methods would be more complicated.
- 5G candidate technologies are more abundant and its application scenarios are more complicated.
- The software evaluation for the performance of 5G technical schemes is facing unprecedented challenges.

Software simulation

- The wireless communication systems runs in a real environment which is compatible & volatile.
- It is more feasible and effective to set up a software simulation platform via computer & mathematical modelling , on which software simulation programs can make performance evaluation for the wireless communications modules or systems.

Software simulation

- The new architecture designs the hardware & software jointly , decomposes the computational tasks through master - slave node model and makes layered design for the whole software based on modular design of application module , protocol stalk, message service , connectivity management , mobility management & system interface function.

Complete simulation system

- Requirement analysis : a networking scenario is needed to be given, including network type , network element type, network interface function , network configuration parameter, services characteristics , performance indicators etc.
- System modelling : it includes abstracting & modeling the network & system components & then outputting the simulation model . these models describe the input output relations of the network & system components.

Complete simulation system

- Evaluation criteria : through the analysis of original requirements, the input information of simulation evaluation can be obtained, which includes performance indicators, simulation benchmark and evaluation criteria.
- Simulation realization : it includes three elements: simulation system architecture , simulation methodology , simulation process.

5G Software simulation requirements

Simulation Requirements analysis

- Comprehensiveness is the functional requirement of the software simulation system , which mainly refers to the comprehensive support for 5G performance indicators and candidate technologies .
- 5G performance indicators include KPI's such as peak data rate , guaranteed min. user data rate, connection density, service traffic volume density, wireless delay, end - to - end delay.

Simulation Requirements analysis

- Software simulation system must provide corresponding modeling , statistic and evaluation of these new performance indicators.
- 5G candidate technologies can be classified into two types : namely air interface technology and network technology.

Simulation Requirements analysis

- New technologies in architecture level, such as SDN & SON, have the greatest impact on the design of software simulation system because it needs to model the new network architecture, design new network element types, interfaces between new n/w elements & new protocol stacks.

Simulation Requirements analysis

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Simulation Requirements analysis

- Rapidly is the time efficiency requirements for software simulation system.
- Accuracy is performance requirement for software simulation systems. Common ways to improve the simulation efficiency from the perspective of hardware configuration : high configuration desktop , multi core servers , high performance super computers.

Technological impact analysis

Simulation Requirements analysis

The main factors influencing the system simulation software design and implementation can be divided into three categories:

- Architecture
- Function
- Performance

Performance shows the computational performance that can be reached by system simulation software and its platform.

5G software link level simulation

Link technology overview

- 5G transmission technologies will explore a series of new types of multiple access & transmission mechanisms, to greatly improve the spectrum efficiency & energy efficiency of wireless systems.
- Massive MIMO has become one of the important 5G key transmission technologies.

Link technology overview

- Massive MIMO can bring the huge array gain and the interference suppression gain through large-scale antenna arrays, thus greatly improving the system spectrum efficiency and the edge user spectrum efficiency.
- In 5G network deployment , will have distinctive heterogeneous characteristics

Link simulation realization

Simulation key factors

- The link level simulation is mostly used to evaluate the physical layer transmission performance of the wireless communication systems.
- Through modular simulation design , the link level simulation can realize the performance comparison of different transmission schemes with a variety of transmitter structures and receiver algorithms.

Simulation key factors

- 5G transmission will pose higher requirements for the computing abilities and the simulation speed of the link level simulation.
- The factors that need most consideration in the link level simulation of the main candidate technologies include the following aspects :

Simulation of Massive MIMO channel

- In terms of 5G link level simulation, it is necessary to carefully consider various characteristics of massive MIMO channel such as spatial correlation , the coupling, the near field effect etc.
- The empirical channel model can also be constructed through analysis, comparison and fitting of the measured channel data in combination with theoretical analysis.

Simulation for the neighboring interference

- In 5G scenarios with ultra dense nodes, the co-channel interference will limit the network capacity.
- The interference signals can also be theoretically modelled through theoretical derivation in order to simplify the simulation complexity.

Simulation for the novel multiple access technology

- It needs a comprehensive evaluation on the impact on the spectral efficiency and the impact on the robustness of the non-ideal factors such as frequency offset and channel estimation errors.

Simulations with high-performance multi-core parallelization

- 5G system will be configured with massive number of antennas.
- The multi-thread parallel simulation, the high performance multi-core server , the software and hardware co-simulation and other advanced simulation methods will be conducive to the fast and accurate link level simulation evaluation.

Simulation process overview

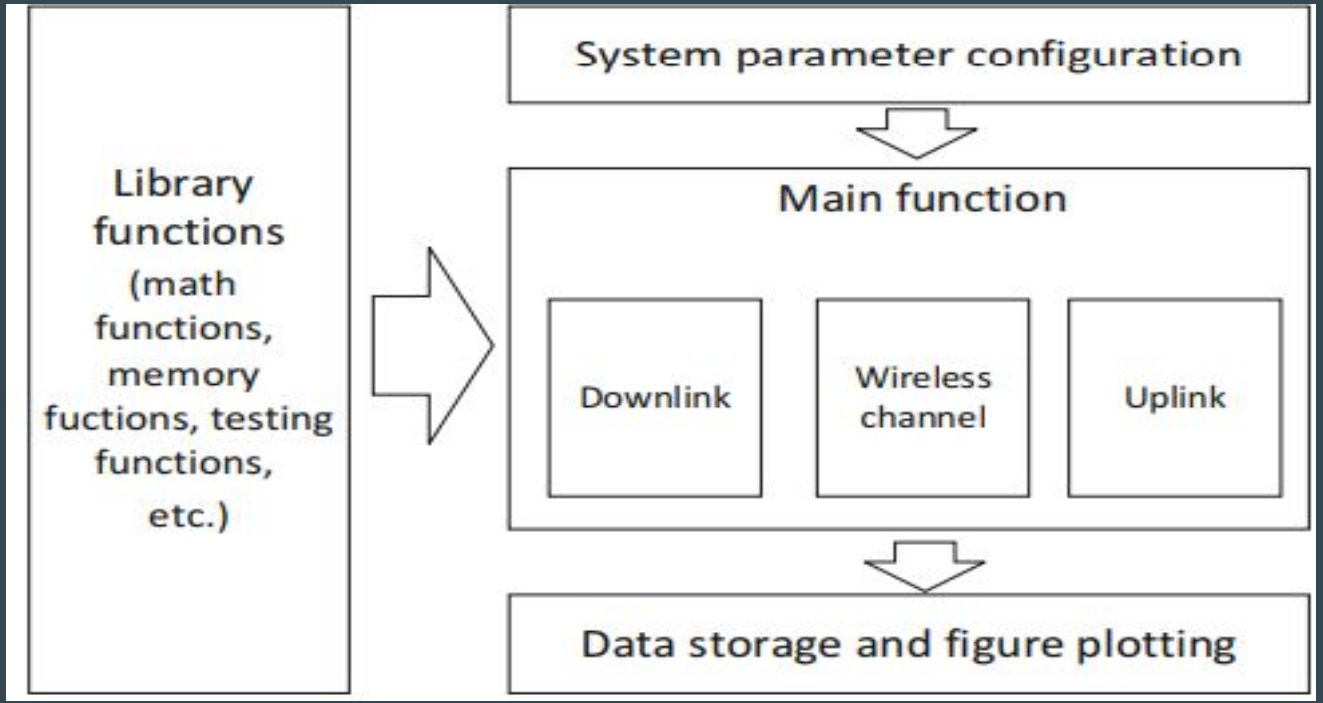
Simulation process overview

- The signal processing modules at the transmitter mainly include channel coding , constellation mapping , multiple antenna precoding , multiple access , reference signal generation , framing etc.
- The signal processing modules at the receiver mainly include cell search and synchronization , de-framing , channel estimation , multiple antenna detection , demodulation , channel decoding etc.

Simulation process overview

- In the link level simulation, programming is required to realize each of the above mentioned function modules.
- The wireless link level simulation system usually includes two sets of simulation systems for DL & UL.

Simulation process overview



Simulation process overview

- It may include system level parameters such as the frame structure , the system bandwidth , cell information , resource allocation methods etc.
- Realization of each function module in UL & DL and the interface definition between modules are the most basic parts of link level simulation.

Introduction to simulation cases

Massive MIMO performance simulation

- Turbo ⅓ code rate & quadrature phase shift keying (QPSK) modulation are used.
- Adaptive modulation & coding (AMC) & HARQ mechanisms are not initiated.
- In the massive MIMO simulation, the number of BS antenna is set to 128, and the number of users took K= 20,30,40,50 respectively.

Massive MIMO performance simulation

- Reasonable parallel simulation can greatly reduce the simulation time.
- To accelerate the process, the parallel optimization is carried on.
- The link simulation consists of two layers of cycles, SNR cycle and frame cycle.
- Data in the SNR cycle and frame cycle are independent.
- Parallelization of the SNR and frame cycles is simple and effective way to improve simulation timeliness.

Massive MIMO performance simulation

- The theoretical parallel speedup result of the new parallel simulation method can be faster in orders of the number of SNR times by the number of frames.
- Parallelization of the SNR and frame cycles is simple and effective way to improve the simulation timeliness.

Heterogeneous network energy efficiency simulation

Heterogeneous n/w energy efficiency simulation

- The wireless heterogeneous network is an effective means to alleviate the contradiction between data growth and energy consumption.
- The indicators have considered the impact of the new BS layout on the energy consumption increase at the network side and the energy consumption changes at the terminal side at the same time.

Simulation parameters

Macro cell parameters

Carrier frequency	2.0 GHz
Bandwidth	20 MHz
Path loss model	COST-231 - Walfish - Ikegami model
Cell radius	5 Km
Minimum SNR requirement	10 db
Noise	-160 dbm/Hz

Simulation parameters

Low power consumption cell parameters

Carrier frequency	2.0 GHz
Bandwidth	20 MHz
Pathloss model	COST 231- Walfish - ikegami model
Minimum SNR requirements	10 db
Noise	-150 dbm/hz

Simulation parameters

Micro-cell user parameters

Active user density	10^-5 user / m^2
Working state power consumption	1.2 W
Resting state power consumption	0.6 W
Packet size	100 bit

Tail-Biting convolution code decoder simulation

Tail - biting simulation

- In the short packet transmission, short codes are usually needed for channel coding such as tail-biting convolution codes.
- tail - biting convolution codes usually use circular viterbi algorithm (CVA) for decoding.
- Detection of the circular trap can be used to help control the CVA decoding process, so as to get the fast convergent iterative decoding algorithm.

Compressive sensing simulation

Compressive sensing simulation

- It is an important way of data processing, which can recover the raw data from extremely few sample values.
- The computational complexity of compression sampling is much lower at the transmission than that of receiver.

Compressive sensing simulation

- CS technology has a great application prospect in the sensor network data aggregation application.
- Treelet based compressive data aggregation (T-CDA) is also a data collection method.

User-oriented link adaption in D2D network coding multicast

User-oriented link adaption

- D2D is a candidate technology in 5G.
- In user - oriented link adaptive method , two multicast channels whose link quality corresponds to the maximum value of the modulation type and the minimum value of coding type are chosen.
- In order to verify the algorithm's BER and spectrum efficiency, link simulations are carried out

5G software system level simulation

Test evaluation methods

Test evaluation methods

- A good evaluation system requires basic features of completeness , simplicity, better usability etc.
- For the comprehensive , accurate and efficient evaluation of 5G network technologies, the study should at least include following aspects :
- Design of new performance indicators
- Redesign of traditional indicators in 5G network
- Network function virtualization

Design of new performance indicators

New KPI's introduced by 5G networks are :

- Connection density
- Traffic volume density
- Minimum guaranteed rate

Redesign of traditional indicators

- Virtual resources model is introduced after introduction of the virtual technologies.
- There are big breakthroughs and innovations in some 5G new technologies in terms of design of network resources model and new concepts and designs are introduced , which are not compatible with designs in the past.

Network function virtualization

- There can be three layers : infrastructure layer , control layer and application layer.
- Infrastructure layer : it is supported by various kinds of network equipment nodes such as macro eNB and micro eNB.
- Control layer : it is composed of a series of distributed management node.
- Application layer : it is made up of many different services and applications.

Network function virtualization

- Infrastructure layer is supported by various kinds of network equipment nodes, such as macro eNB and micro eNB.
- The services are scheduled and allocated by management nodes.

Key simulation technologies

Key simulation technologies

Key technologies of 5G system simulation design are :

- Dynamic simulation modelling technology
- Management technology of virtualized computational resources.
- Multi-core parallel simulation technology
- Hardware acceleration simulation technology
- Real time transmission technology

Dynamic simulation modelling

It is embodied in following aspects :

- Networking scenario is complicated & changeable
- Network model is evolving

Dynamic simulation modelling process

It is composed of following steps :

- The simulation model is decomposed. It is composed of 5 layers.
- Simulation parameter library is generated according to the model and the requirements.
- The corresponding function libraries are mapped by the model.

Dynamic simulation modelling process

It is composed of following steps :

- According to the simulation requirements, the mapped function library and parameter library are organically organised to become a complete simulation process.
- By dynamically configuring the parameter library, function library and the simulation process , we can get the specific simulation tasks, which can get the specific simulation tasks , which directly faces the users and need to provide friendly configuration management interface.

Virtual computational resources management technology

The virtual computational resources management technology is broken into three parts :

- The simulation requirements are mapped into computational tasks that can be deployed independently.
- Various kinds of hardware resources can be virtualized into three kinds of virtual resources : computational, storage & communication resources.
- Binding the virtual resource dynamically to computational tasks.

Key simulation technologies

Multiple -core parallel simulation technology

- Simulation platform design based on multi-core parallel computation covers hardware, operating systems, parallel technology, simulation software, models and algorithm designs etc.
- From the hardware level, parallel server scheme or high performance host system can be chosen to support high computing power.

Multiple -core parallel simulation technology

- Operating system allocates process, storage and other hardware resources for parallel tasks, realizing the inter-process communications.
- Parallel technologies generally include messaging, shared storage and data parallel.

Multiple -core parallel simulation technology

- Parallelization of simulation software is the key work of multi-core parallel design of simulation platform, which need to consider the following design requirements :
- Simulation software is decomposed in parallel from the aspects of function, algorithm and operands.
- The reasonable division design of simulation function modules can reduce the communications data between parallel sub tasks.

Multiple -core parallel simulation technology

Multiple CPU-GPU heterogeneous platform has multiple layers of parallel execution ability in task level and data level.
The model's mapping process has the following three levels :

- Mapping from simulation model instance to logical process.
- Mapping from logical process to thread.
- Mapping from thread to processor cores.

Hardware acceleration simulation technology

- It uses hardware modules rather than the software modules to make full use of the inherent fast hardware features.
- Hardware uses high performance FPGA board which has strong computing power and logical processing ability.
- FPGA board has stronger floating point computing power than CPU server & stronger task management, resource scheduling and other logic handling abilities than GPU server.

Hardware acceleration simulation technology

The implementation process of hardware acceleration simulation is:

- Key technology research
- FPGA based hardware accelerator card system is designed.
- Configuration data is loaded.

Real time transmission technology

- Network architecture can extend hardware processing ability of the simulation platform through the way of extending server nodes.
- After the high strength computational tasks are parallelized, the computational time of each independent parallel subtask becomes shorter, which is usually within hundreds of microseconds.

Introduction to simulation cases

Massive MIMO system level simulation

Simulation parameter description

- It uses MU-MIMO model to simulate LTE DL system performance.
- Channel matrix formed with 128 BS tx antennas, 1 rx antenna , 15 users scheduled in a single cell at the same time.
- CPU memory : 256GB
- Windows server
- MATLAB

Radio resource optimization Of UDN

- Site number required to be coordinated will also increase in resources allocation, making resource allocation more difficult.
- The site deployment in hotspot areas shows a trend of high density and no programming.

Statistical modelling simulation

This simulation is of UL interference

- In OFDMA based frequency multiplexing network, inter-cell interference has become one of the key factors that restrict the improvement of system performance.
- In the past network deployment, it is often difficult to choose appropriate control parameters and only conservative settings can be made according to limited experience.

Local mobile cloud assisted computation offloading

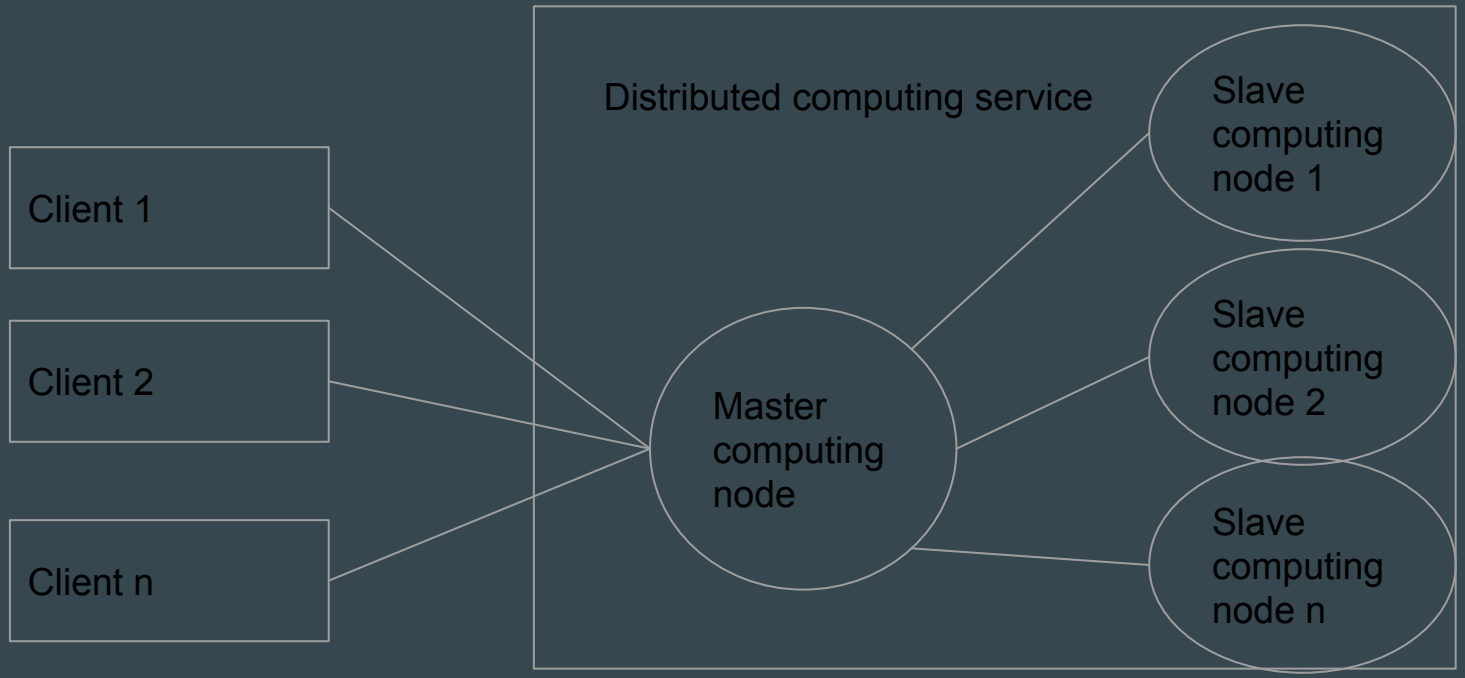
- Computation offloading technology is an important application of mobile cloud computing.
- It offloads the user's local computational tasks to the cloud with rich resources and extends the computing power of the mobile terminal with limited resources, so as to use the new computation intensive applications.

Software visualization of 5G network simulation

Architecture summary

- Simulation platform for 5G based on the universal software and hardware platform. This platform adopts the distributed master-slave parallel processing architecture.
- The master computational node is the management centre of the simulation platform.
- The slave nodes are managed by master nodes, take on computational tasks of the master node, and report the simulation results.

Architecture summary



Architecture summary

- Sim

Evaluation test of hardware and software co-simulation

Overview

- The concept of hardware and software co-simulation was proposed as early as deployment of HDL.
- It reflects the idea of authenticity and rapidness , which is an effective testing and evaluation method to deal with rapid development of 5G.

Requirements

- Authenticity
- Rapidness

Composition

- In this, the physical layer of the simulation platform is partially substituted by the real physical layer and the transmission network , which can increase the reality and instantaneity of the system.
- Mapping relation from the system level simulation software to the real physical layer should be customized in order with the specific requirements of the simulation evaluation.

Hardware test evaluation platform

5G hardware test evaluation platform

- The constitution of typical hardware test platform of 5G evaluation includes parallel channel sounder platform of channel measurement and modelling .
- A MIMO OTA platform of designated channel model, a platform of software and hardware of open source community and terminal and base station system based on the general purpose processor.

Key technical challenges

- Synchronization across multiple channels.
- Real - time storage of massive raw measurement data
- Parallel channel calibration
- High speed continuous storage of raw data

OTA test platform

- The method to evaluate radiation performance of traditional SISO is mature.
- Its evaluation mainly aims for two indicators , making OTA test for total radiated power (TRP) and total radiated sensitivity (TRS).
- Many performance parameters of passive MIMO antenna, such as efficiency, gain are not different from traditional SISO antennas.

OTA test platform

- MIMO antennas contain many antenna elements, passive parameters are introduced to describe the relationships among several antenna elements.
- The MIMO OTA test scheme is essentially a different simulation method of multipath in space propagation environment , producing wireless communication environment close to the reality to deal with the key challenge in massive antenna MIMO OTA testing technique.

Field Trail network

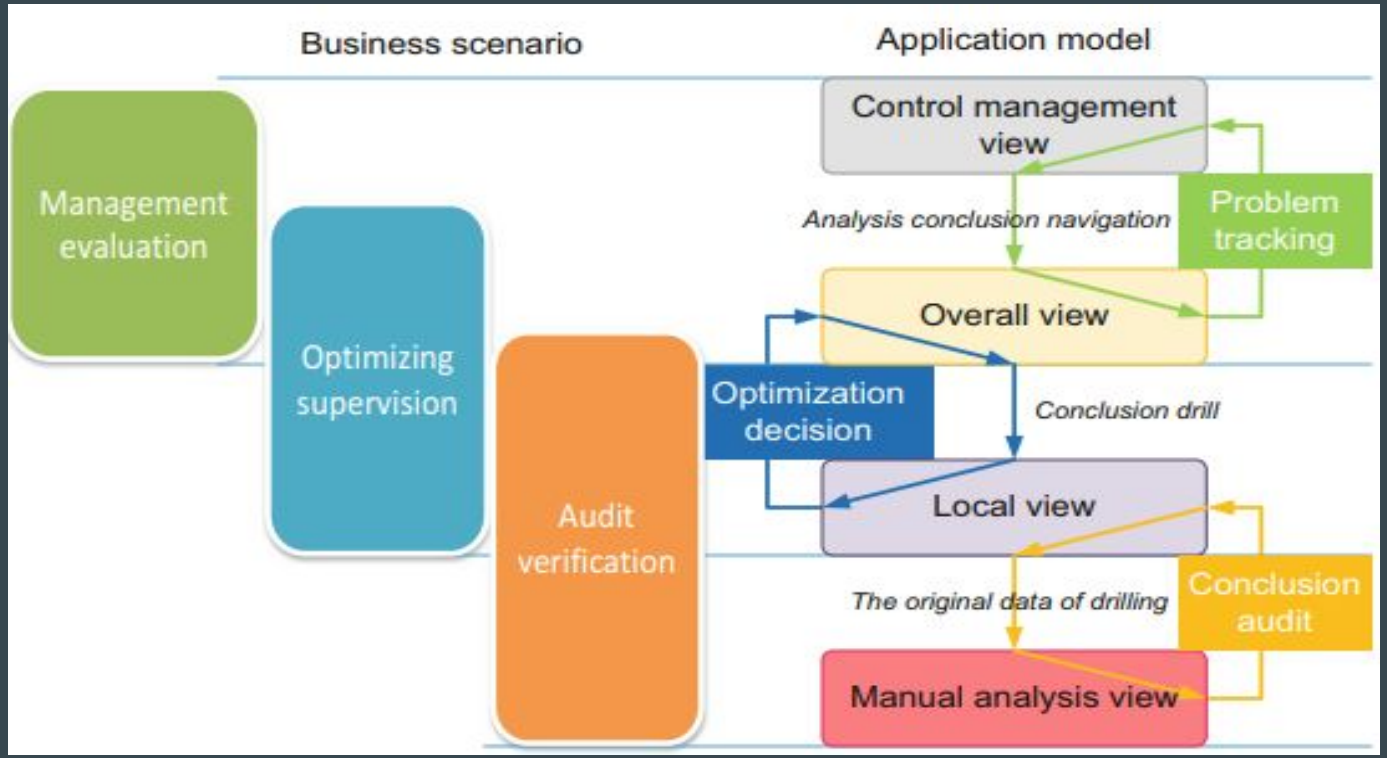
Requirements and technical challenges

- Various application scenarios
- Technical challenges in field trail
- Development status of 5G testbed in foreign countries
- Development & evolution of HetNet convergence

Wireless network data intelligence analysis

- Background and necessity
- Key technologies
- Technical roadmap
- Uniqueness
- Status
- Application scenarios
- Innovation points

Working mode of intelligent network optimization analysis system



Thanks ...