ITU KALEIDOSCOPE
NANJING 2017
Challenges for a data-driven society
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Beijing University of
Posts and Telecommunications

Data Driven Future Wireless Communication

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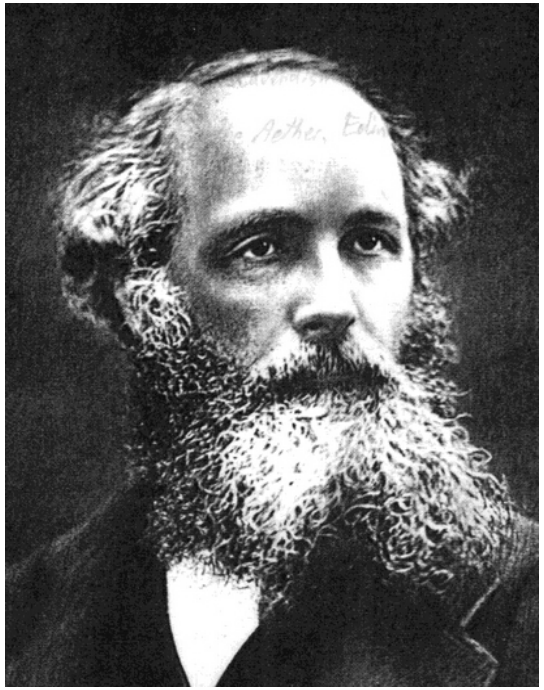
Outline

1. **The requirements to 5G and ITU-R defined vision;**
2. **The exploration to combine data mining/AI with wireless communication;**
3. **Conclusions.**

Magnetic waves and wireless communication

- Maxwell **forecasted** the existence of magnetic waves in **1865 (152 years ago).**



$$\oint_l H \cdot dl = \int_s J \cdot ds + \int_s \frac{\partial D}{\partial t} \cdot ds \quad ①$$

$$\oint_l E \cdot dl = -\frac{d}{dt}\int_s B \cdot ds \quad ②$$

$$\oint_s B \cdot ds = 0 \quad ③$$

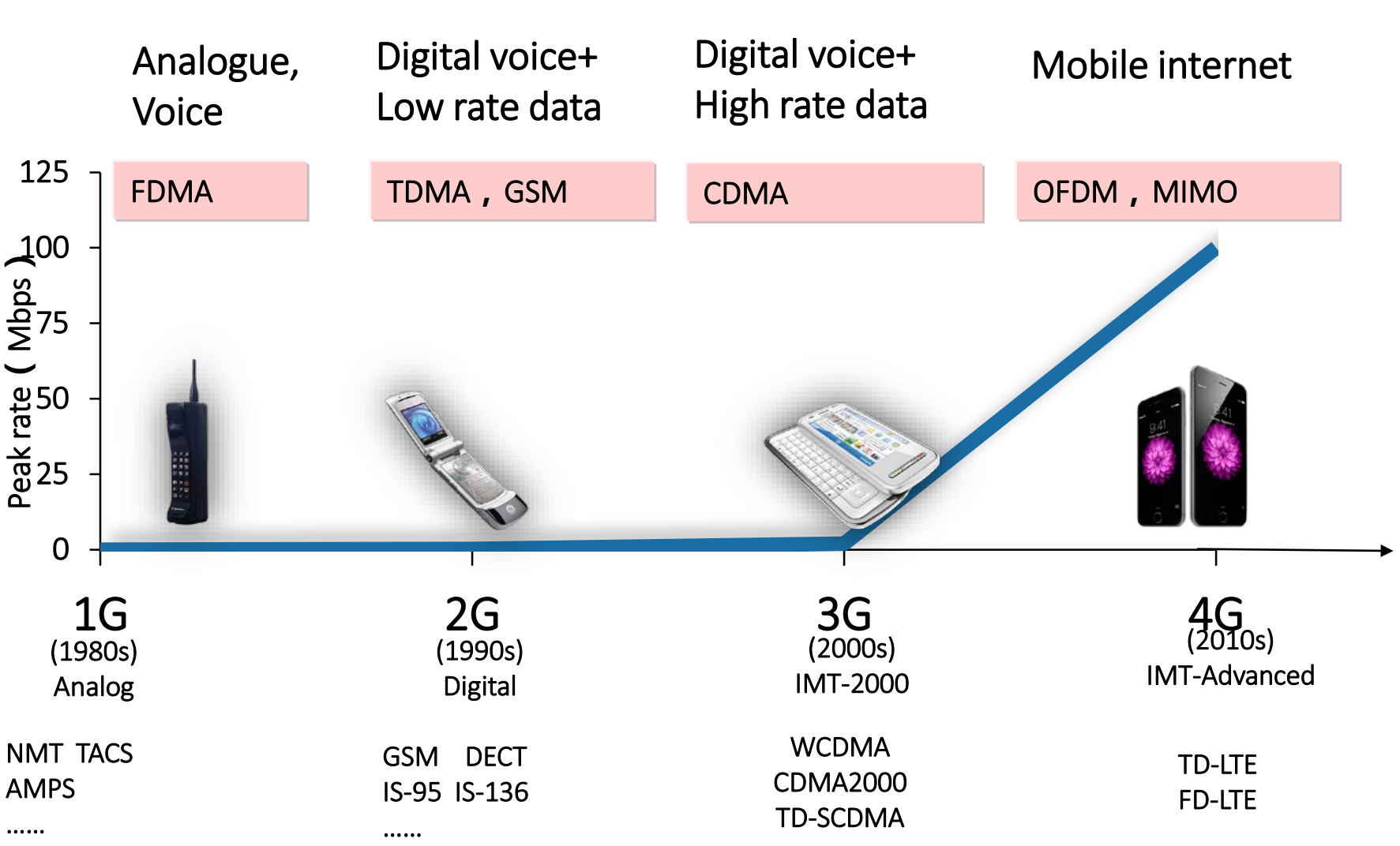
$$\oint_s D \cdot ds = \int_s \rho dv \quad ④$$

James Clerk Maxwell ,
1831∽1879

- Hertz **designed and realized** one set of magnetic wave generator and detector in **1887 (130 years ago),** thus creating the history of wireless communication.

Heinrich Rudolf Hertz,
1857∽1894

The wireless communication: 1 generation/10 years



Top prize of national science and technology Progress Award in 2016.

"4G TD-LTE key techniques R&D"

1.430,000BS

34% of global BSs

0.481billionUsers

31% of global users

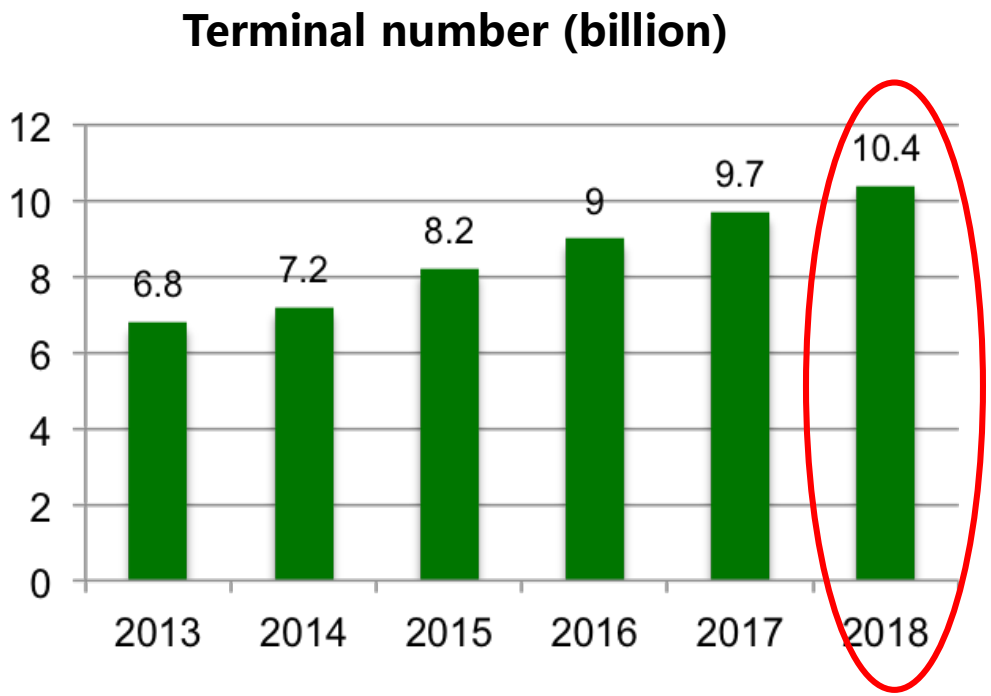
2398+ terminal types

70% below 1,000 RMB

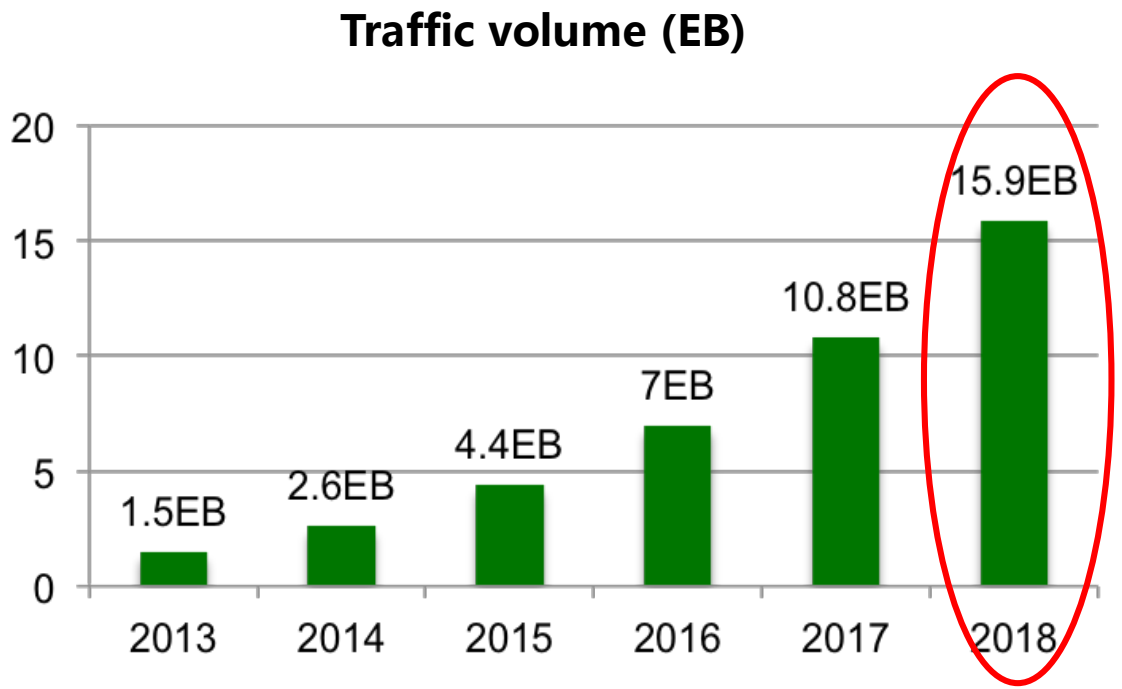
313 cities

Driven power to 5G: traffic volume

- The mobile terminal number is continuously increasing. Its number will exceed **10 billion in 2018**.



- The traffic volume is dramatically increasing. Its volume expands **11 times in past 5 years.**



Driven power to 5G: new services

- The peak data rate requirement will exceed **Gbps** in order to support the new services.

Augmented reality (AR)
/Virtual reality (VR)

Ultra HD video
(4K/8K UHD)

Naked eye 3D

Driven power to 5G: internet of things

- **Wireless communication will penetrate to variety of application scenarios, change the society and life.**

Smart home

Smart agriculture

Environment monitor

Smart car and vehicular network

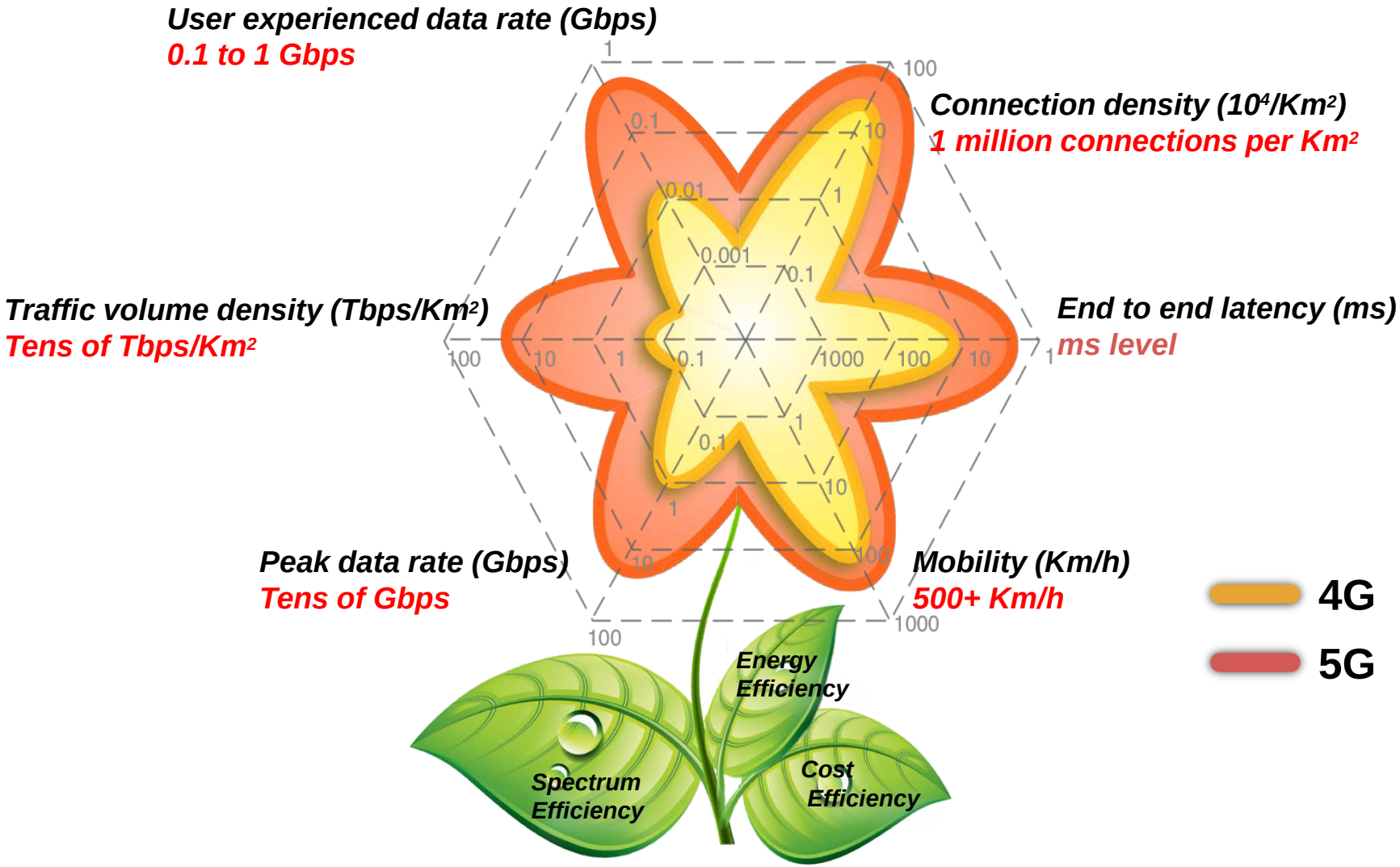
Smart electricity

Factory control

5G vision:
information in a finger away, everything in touch

- **convergence of wireless communication, Internet, Internet of Things (IoT) and Machine-Type Communication (MTC), which brings an explosive increase to traffic volume and stimulates wireless communication to the time of Big Data.**

5G requirements: 5G flower



ITU-R defined 5G requirements

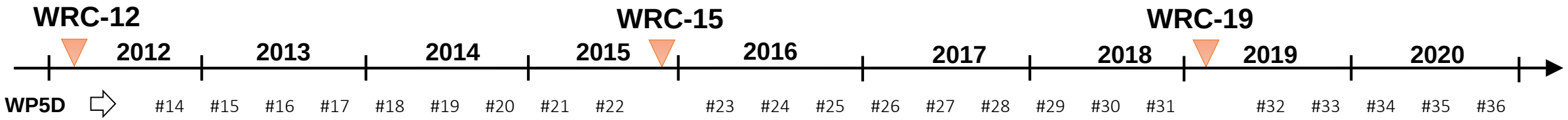
Enhanced Mobile Broadband (eMMB)

Massive machine type (MTC)

Ultra-reliable and low latency (URC)

ITU-R WP5D TD-0625, "IMT Vision – Framework and Overall Objectives of the Future Development of IMT for 2020 and Beyond," Jun. 2015

The timetable for 5G standardization



ITU-R

- vision
- Future technology trend
- **Prepare IMT-2020 Standardization**
- Proposal
- Evaluation and standardization

3GPP

- R11
- R12
- R13
- R14

IEEE

- 802.11ac
- HEW research
- 802.11ax (HEW) standardiza

IMT-2020 (5G) Promotion Group

- Research (Vision, requirements and technology)
- Standard

Outline

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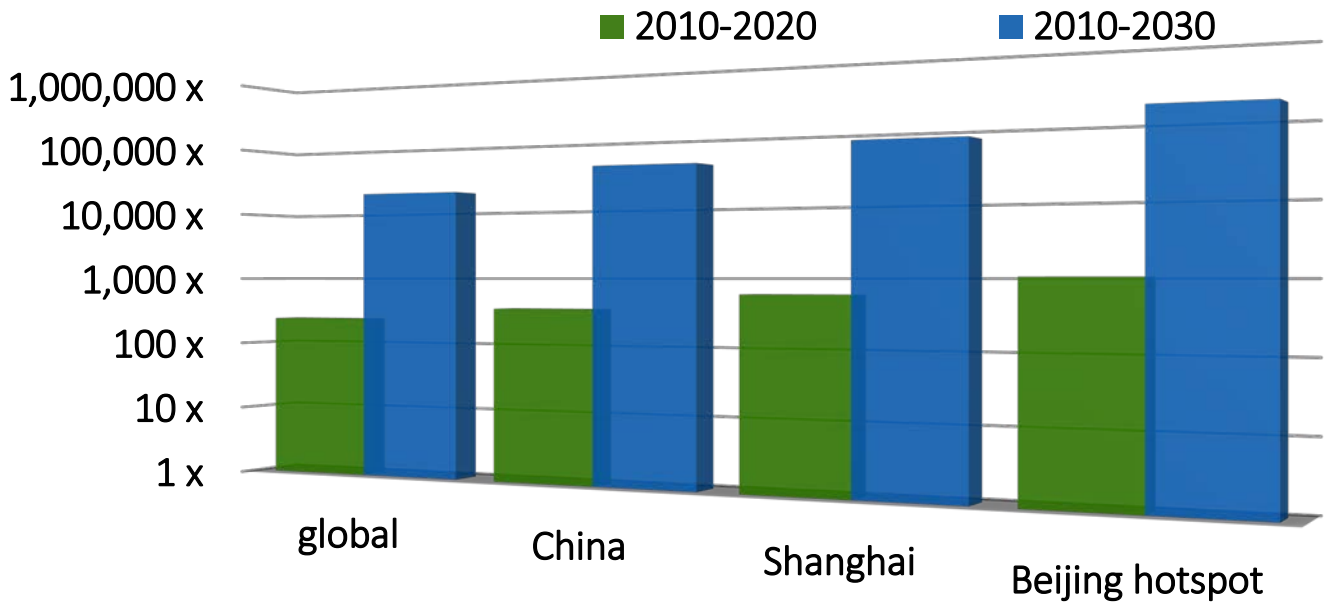
Data appearing everyday in network

- China is increasing higher than other regions and countries (from CMCC report):
  - From 2010 to 2020, it will increase 300 times;
  - Hotspot will reach 1000 times.



0.826 billion users

0.826 bil*12 mon billing record

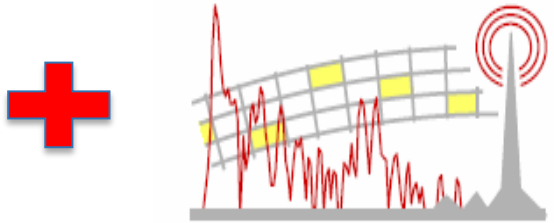
350TB/day signaling log

80TB/day voice and sms

820TB/day internet surfing

Big data and data mining

- On Wikipedia, it is explained as the data volume is so large that it cannot be truncated, managed, processed and transformed within a reasonable time by computer or manpower.
- Data mining is the knowledge discovery in database, i.e., to dig the valuable and hidden principles from big volume data by computing. It is expected that it has the powerful ability to predict the future.



New views and method to solve the conventional problems.

Data mining merges the knowledge of several subjects as computer science, statistics, extraction of information and image processing, etc.

Data mining + wireless communication

- Smart maintenance
- Network planning and optimization
- System design

Network

Advertise ment

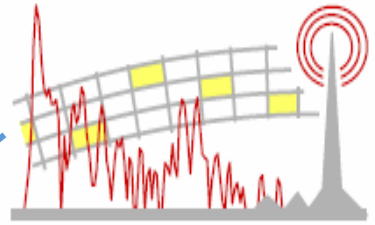
- Real time advertising marketing
- Store / business circle analysis

- Set ordering
- Precise call
- Evaluation to users
- Bad billing risk
- User loyalty

Marketing

Govern ment

- Job site analysis
- Trip analysis
- Public security warning



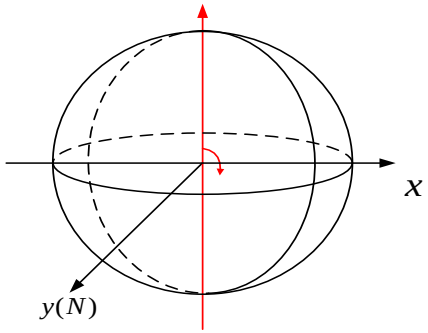
- Quality evaluation
- Terminal preference

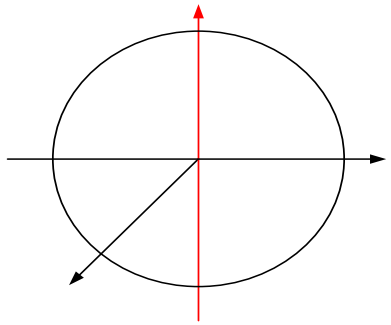
Terminal

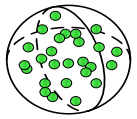
Internet surfing

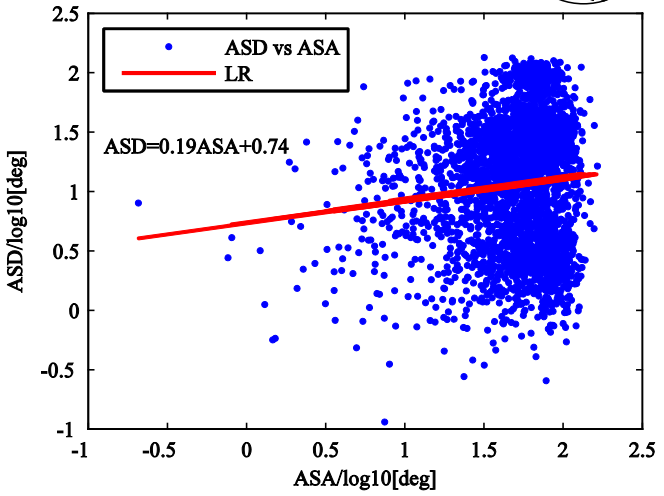
- Internet service
- APP evaluation
- Browse content push
- Financial credit assistant evaluation

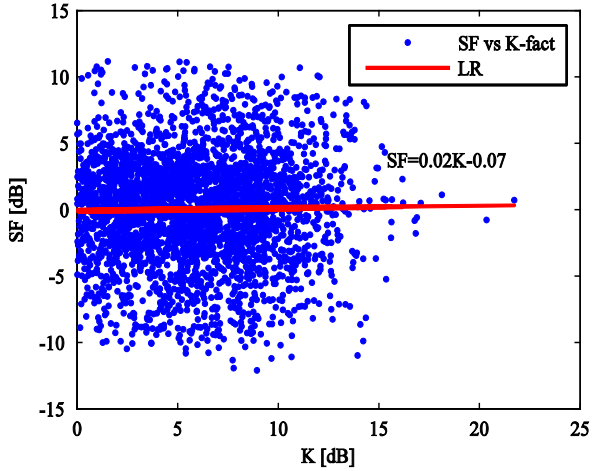
Example 1: the data mining scheme to improve the accuracy of wireless channel

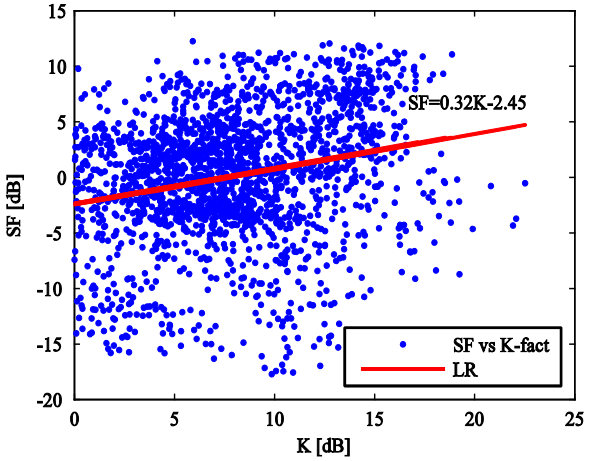


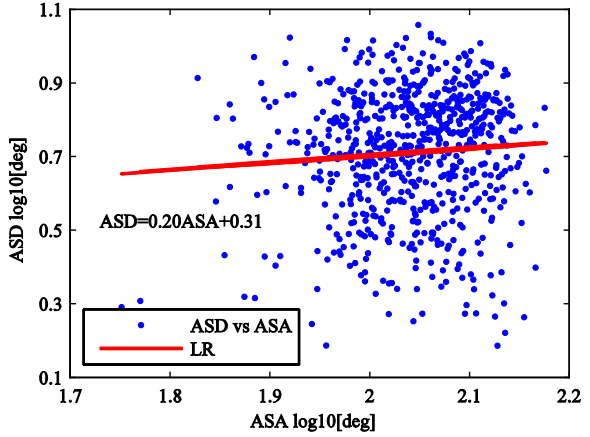












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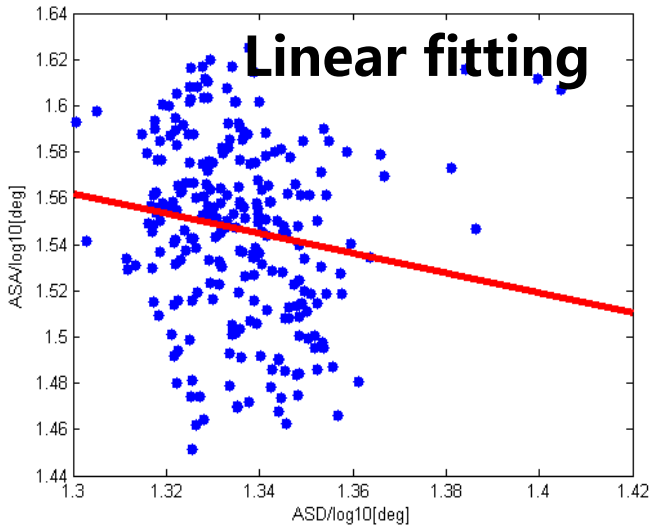
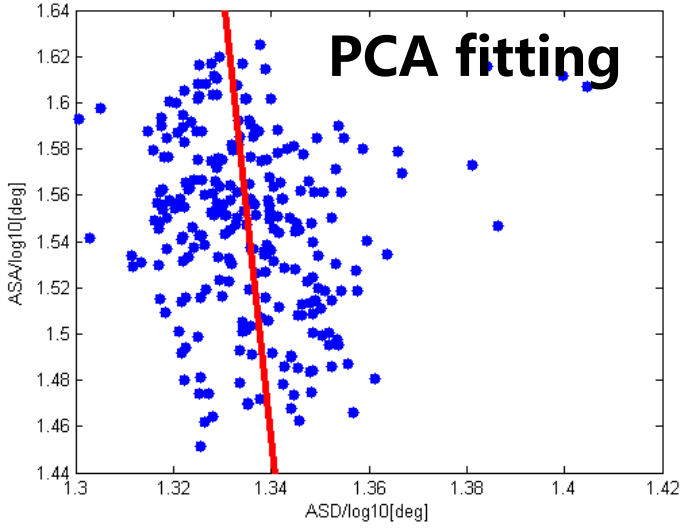




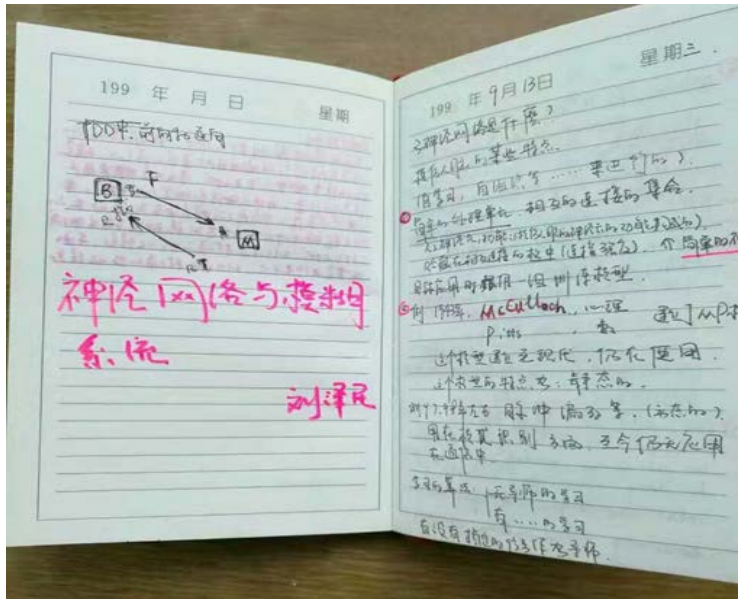
Parameter Dimension	Channel capacity bit/s•Hz	Deviation
9	76.7613	
8	76.9059	0.19%
7	79.2226	3.21%
6	72.6620	5.34%
5	94.8994	23.63%

- **The reconstructed channel capacity variance is less than 5 % if more than 6 dimensions of data are remained, thus it can reduce the complexity of channel modeling significantly.**

Xiaochuan Ma, Jianhua Zhang, Yuxiang Zhang, etal., "A PCA-based Modeling Method for Wireless MIMO Channel", Accepted, IEEE INFOCOM 2017.

5,5,4 with comments "Excellent presentation. the paper is well structured and clear. Innovative approach confirmed by experimentation."

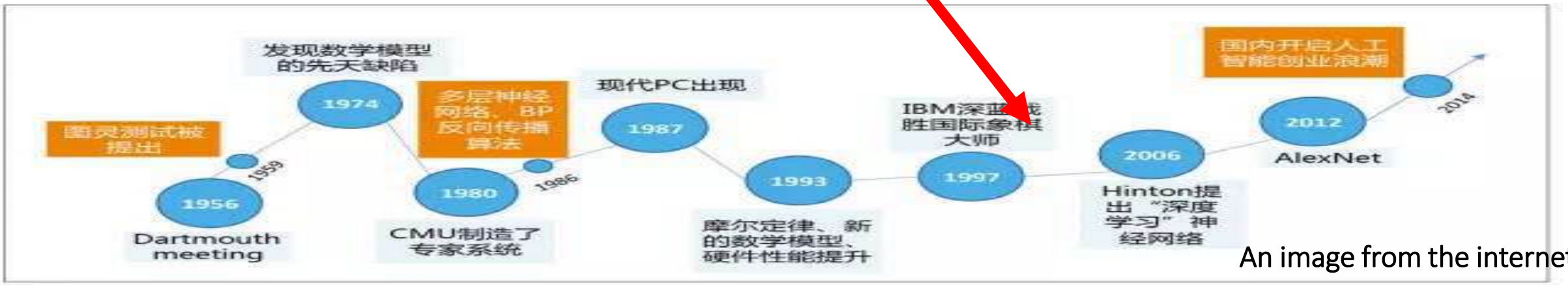
AI— 60 years



Artificial intelligence (AI) :

intelligence exhibited by machines.

- 1999，BUPT
- Neural Network and Fuzzy system
- Prof. Zemin Liu

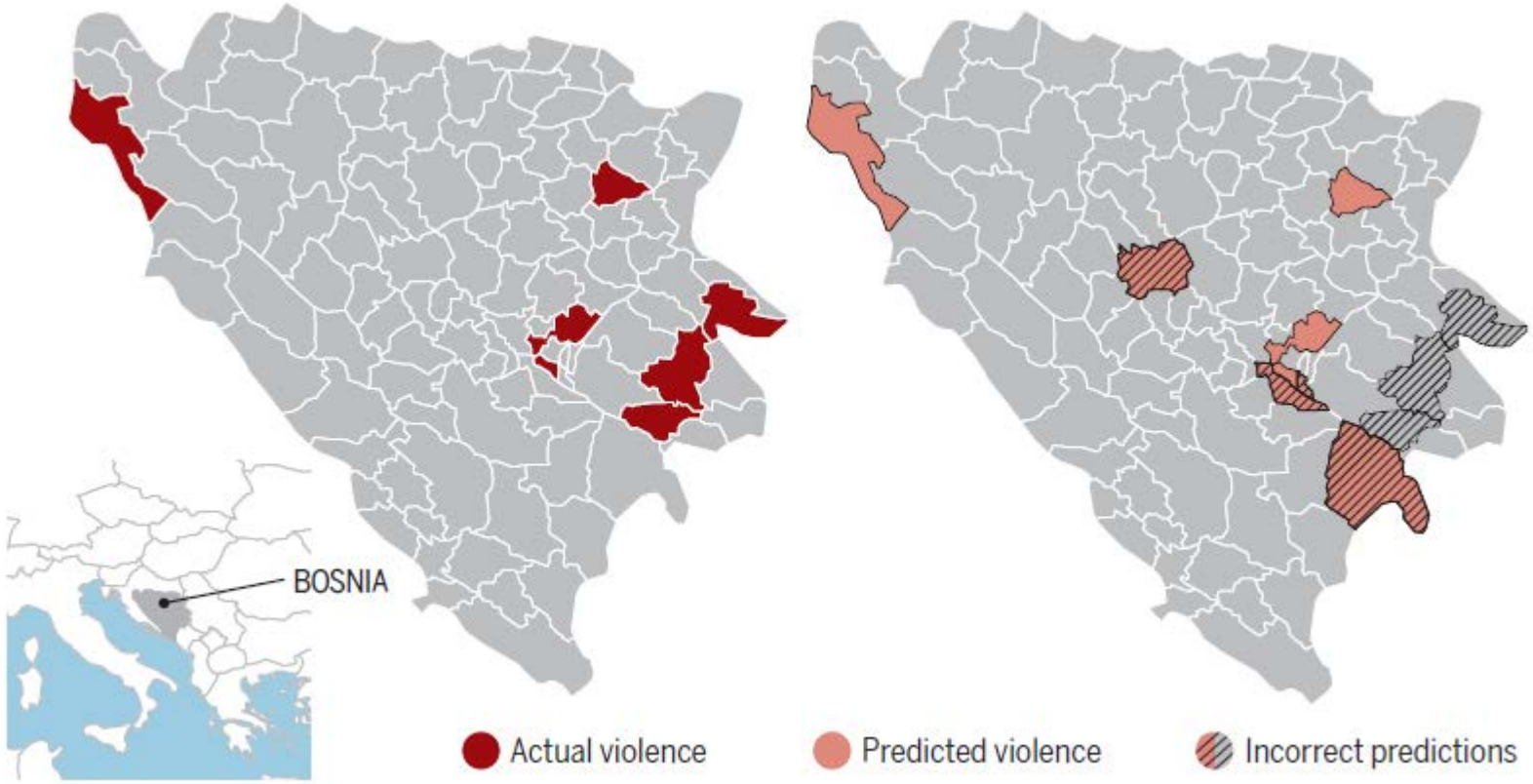


An image from the internet

人工智能发展历程

The predicting ability of AI

- **In February, 2017, Science released a special subject on prediction.**
- **L.E. Cederman, N.B. Weidmann successfully predicted the violent conflict happened in Bosnia (1995) and armed coup in Thailand (2017) .**

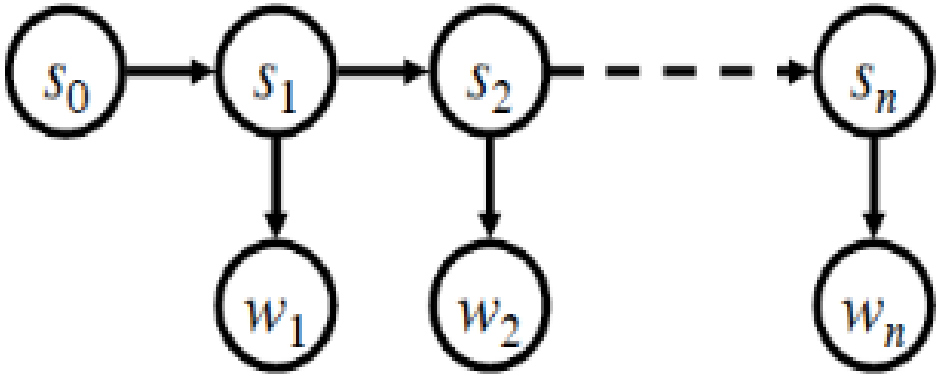


[1],L. E. Cederman, N.B. Weidmann, "Predicting armed conflict: Time to adjust our expectations?", [J]. Science, 2017, 355.

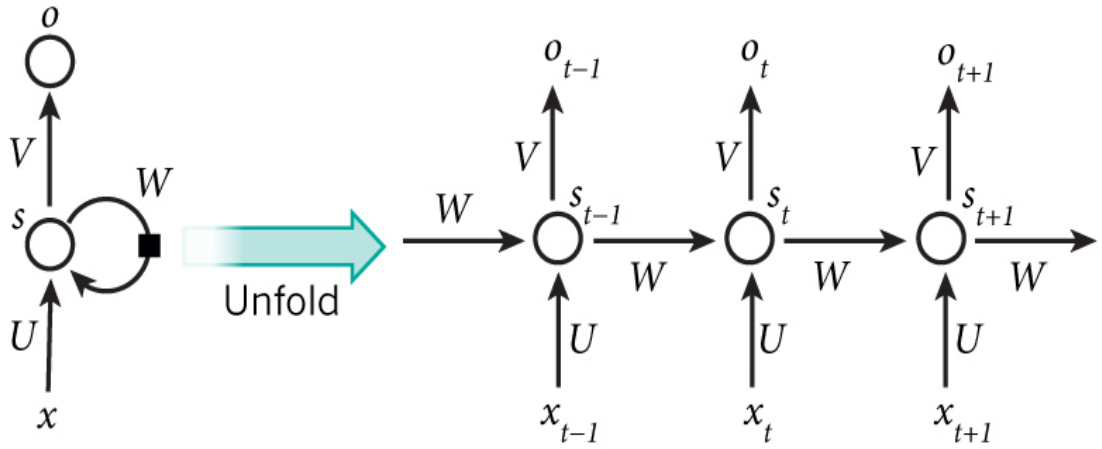
Ideas and principles behind prediction

The predicting ability of AI is due to its capabilities of exacting internal rules from the numerous data and substantiating the rules by the parameters of model.

HMM[1]



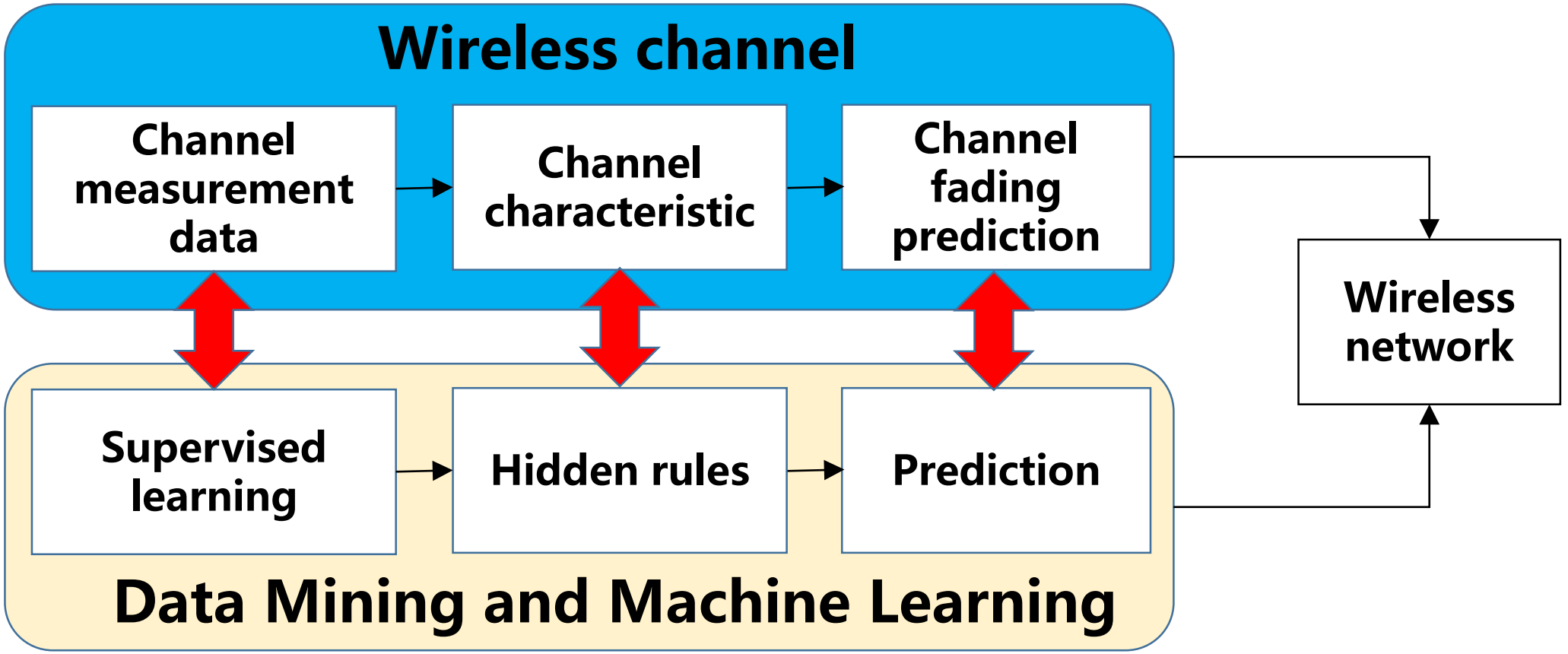
RNN[2]

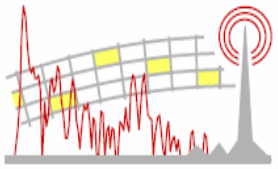


[1].Baum L E, Petrie T. Statistical inference for probabilistic functions of finite state Markov chains[J]. The annals of mathematical statistics, 1966, 37(6): 1554-1563.

[2].Schmidhuber J. A fixed size storage O (n3) time complexity learning algorithm for fully recurrent continually running networks[J]. Neural Computation, 1992, 4(2): 243-248.

Prediction：Joint point of wireless channel and AI





Initial research results of hierarchical prediction

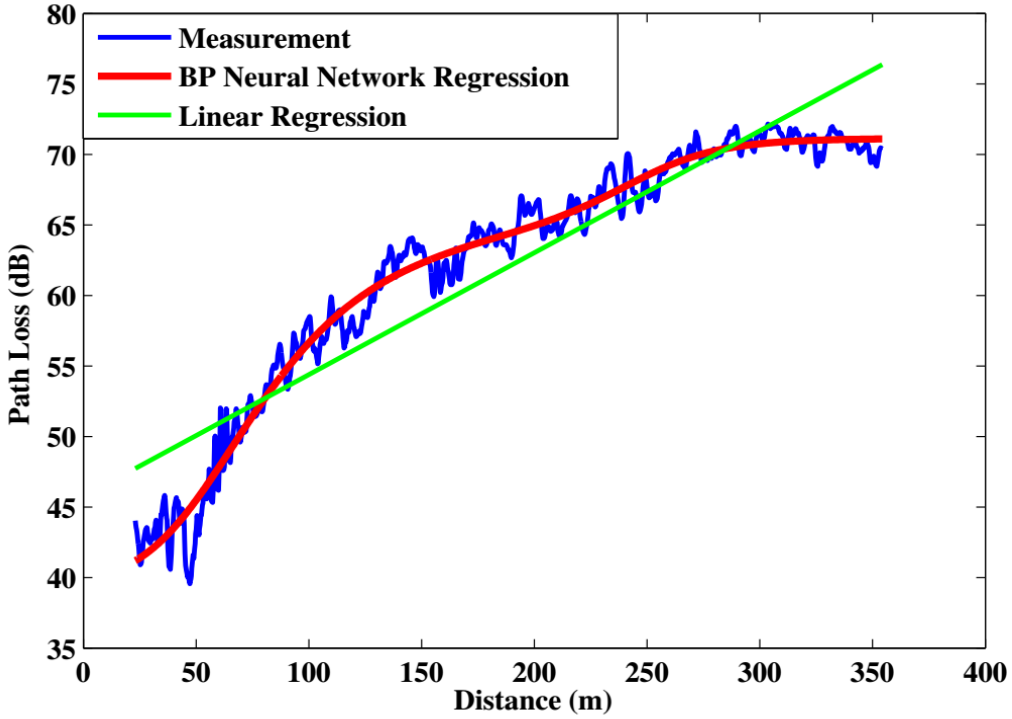


Fig. 7. Result of RMA path loss regression

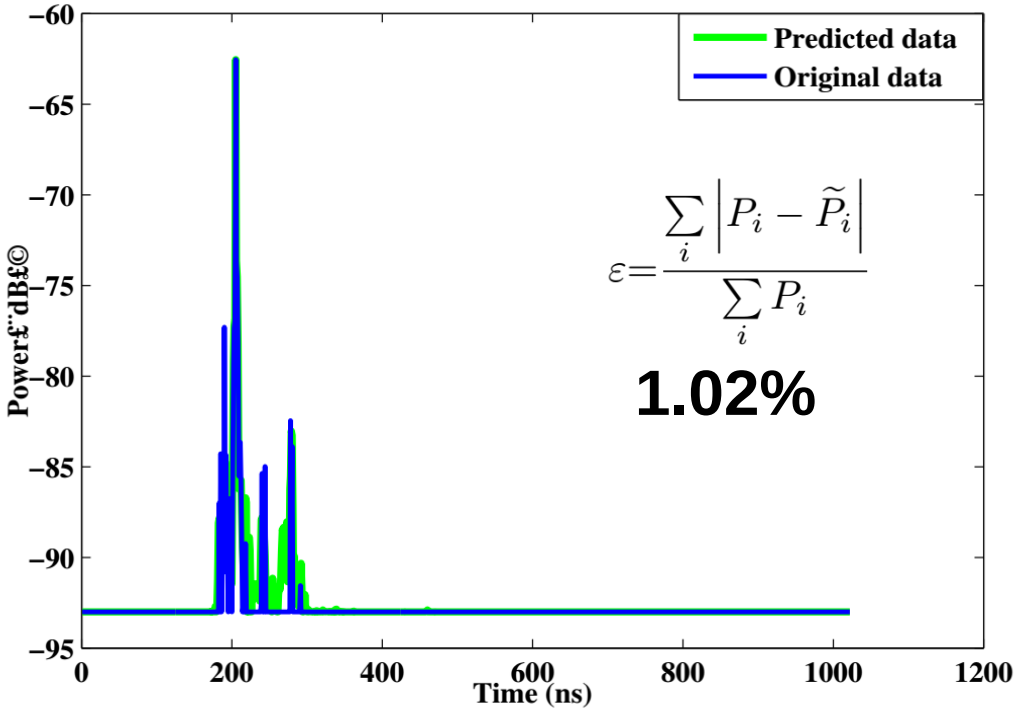


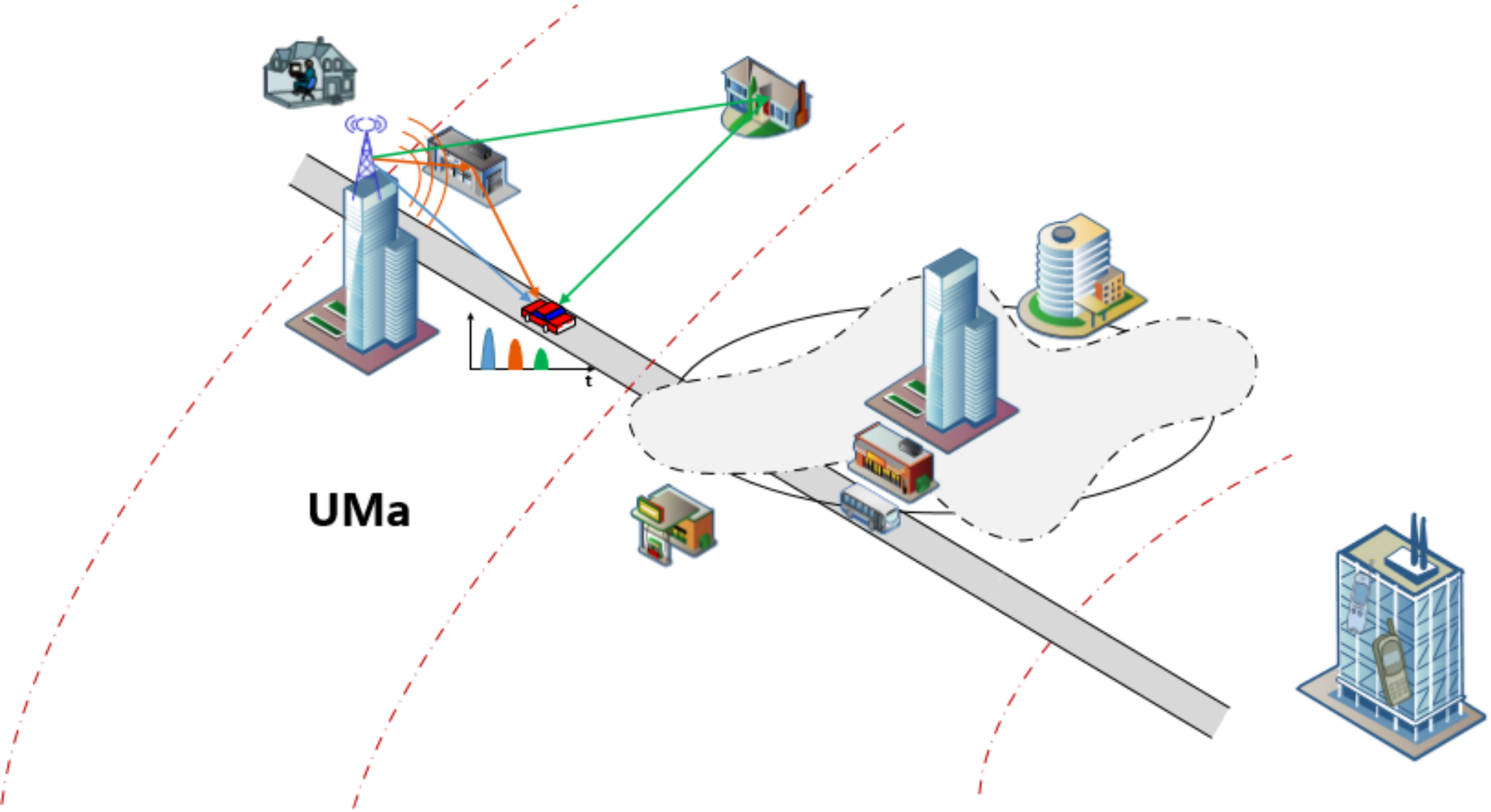
Fig. 8. Result of CIR prediction

Simple BP neural network (one hidden layer, 2 hidden units) to estimate the path loss for the measured path loss

An experiment of CIR prediction is realized by Elman neural network.

Zhang Jianhua. The Interdisciplinary Research of Big Data and Wireless Channel: A Cluster-Nuclei Based Channel Model[J]. China Comm., 5G SI, 2016(S2):14-26.(Best Paper Award)

Example 2： On one’ way to work



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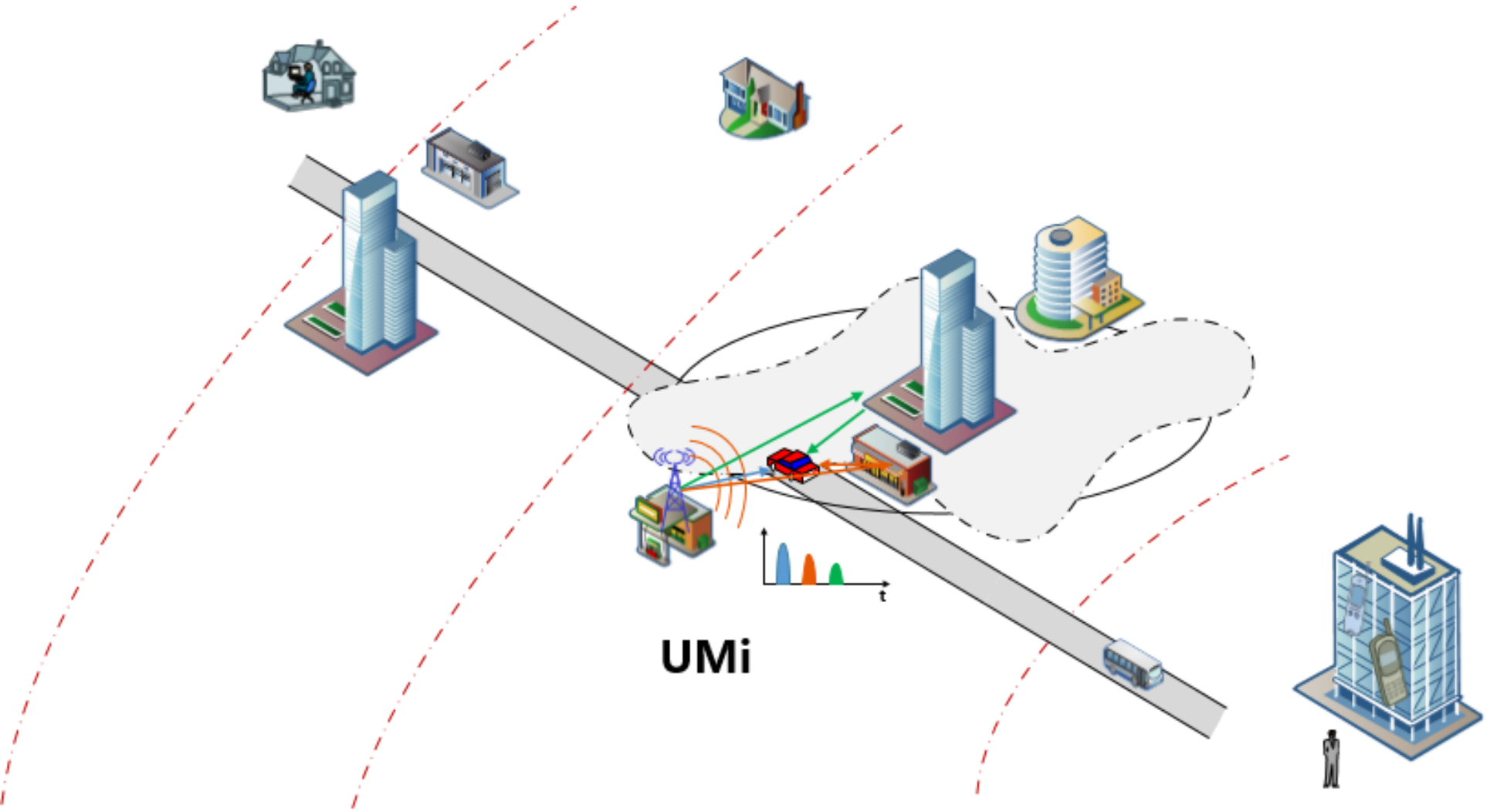

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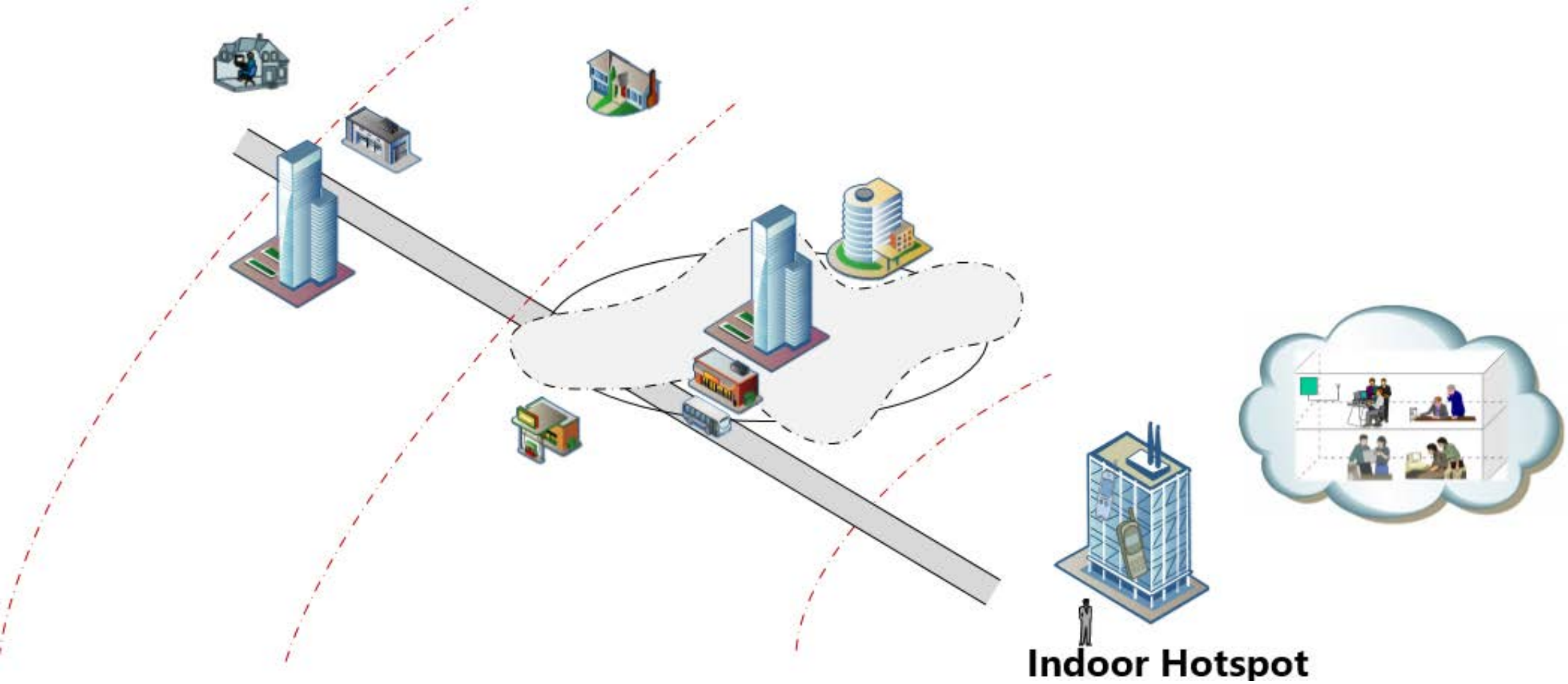
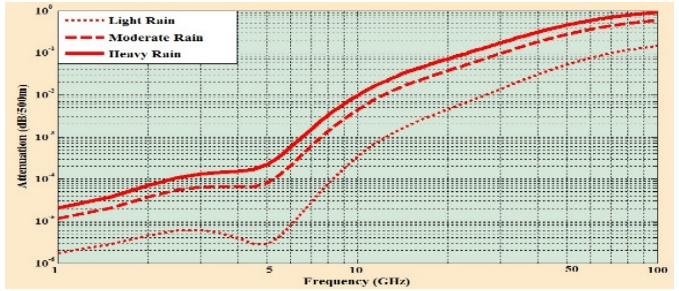


From channel: hierarchical characteristics

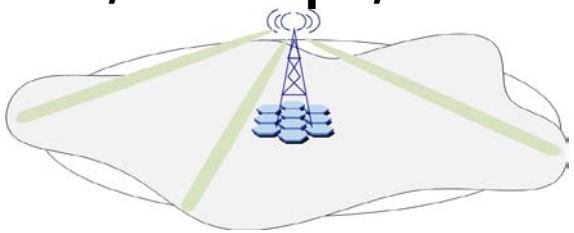
1. Characteristics in Scenario Level :

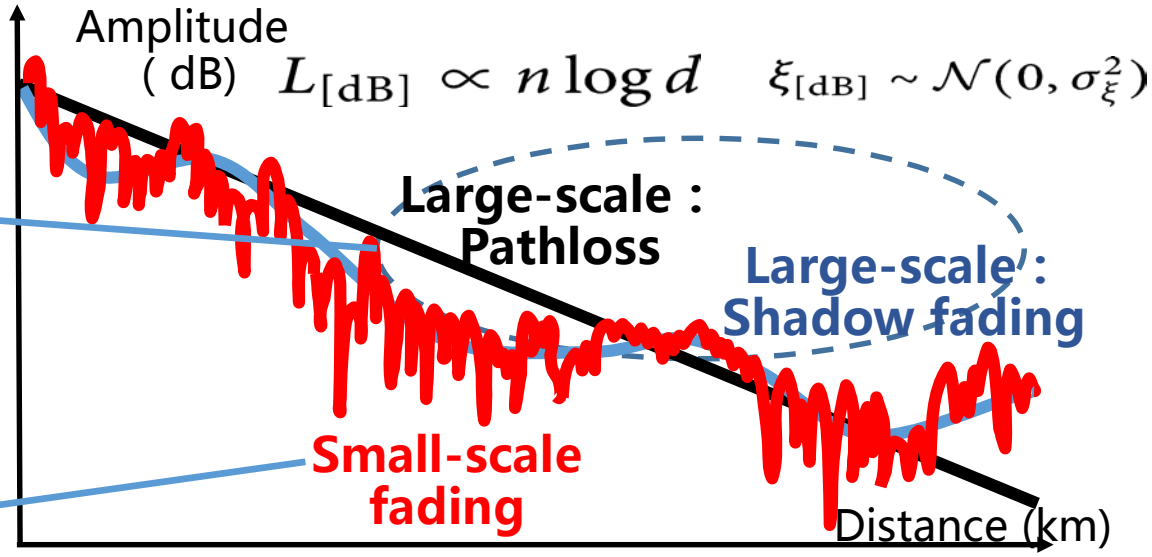
UMi, UMa, RMa, InH, HST , etc.



2. Characteristics in Meter Level :

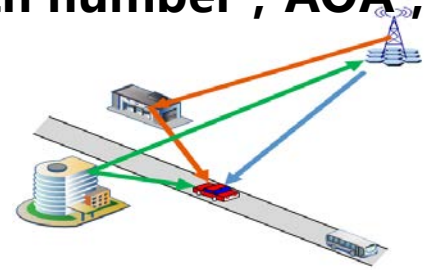
Path loss factor , intercept , shadow fading , etc.

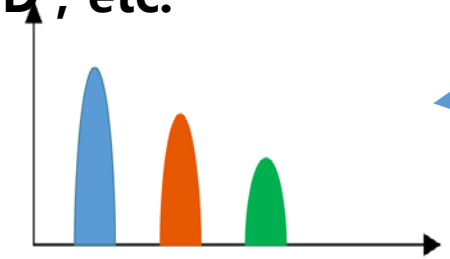




3 , Characteristics in Wavelength Level :

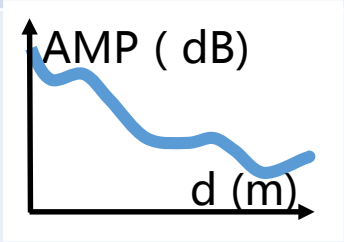
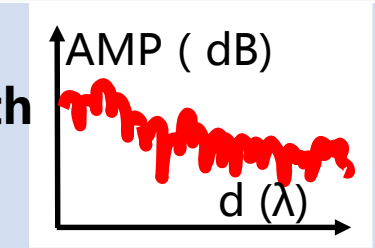
Path number , AOA , AOD , etc.





$$h(t) = \sum_{i=0}^{N} A_i e^{j2\pi f_{di} t + \theta i}$$

Hierarchical Characteristics →Prediction→ Intelligence of Wireless Communication

Level	Joint Point	Difficulty	Learning algorithm
Scenario Level 	Self-organizing networking Optimization arrangement Load adjustment Troubleshooting Service forecast and push	Easy	SVM K-NN (Classification , Clustering)
Meter Level 	RRM : Self-adaption of frequency, antenna and transmitting power	Medium	Neural network (Regression)
Wavelength Level 	RRM+PHY : Channel fading prediction with frequency, spatial, temporal information Self-adaption for frame, pilot, MIMO	Hard	LSTM HMM (Prediction)

Jianhua Zhang, Xiaochuan Ma, Yuxiang Zhang, Zhanyu Ma and Hua Huang , "The Interdisciplinary Research of AI and Future Wireless Communication from Channel Perspective ", Submitted to IEEE network

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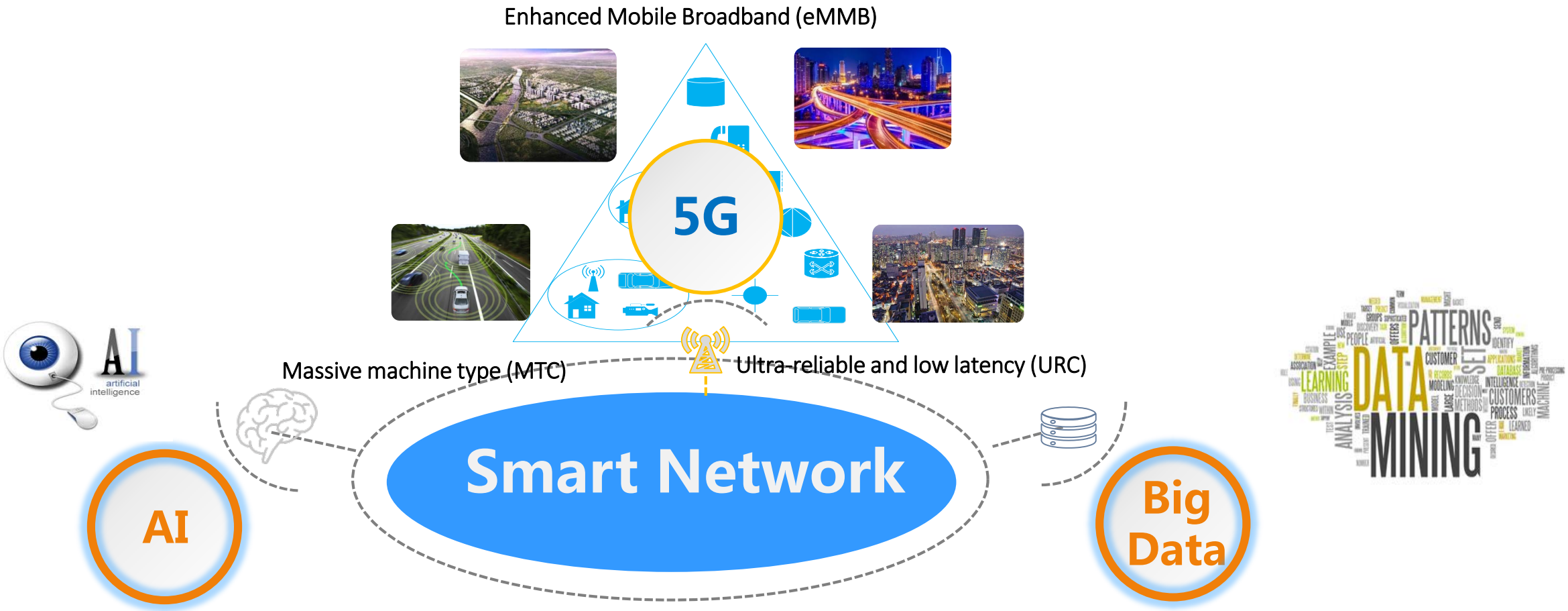
Data Driven Future Wireless Communication



- **Since there are many powerful algorithms in data mining domain/AI to accomplish them, we can expect a data driven future wireless communication to convenient our life and society.**

ITU-R IMT-2020 Draft Group of Channel Model，Precious Comradery！