TM9 Higher Order MIMO Enabler

Maximize Capacity Potential

MWC 2018

26 FEB - 1 MAR BARCELONA

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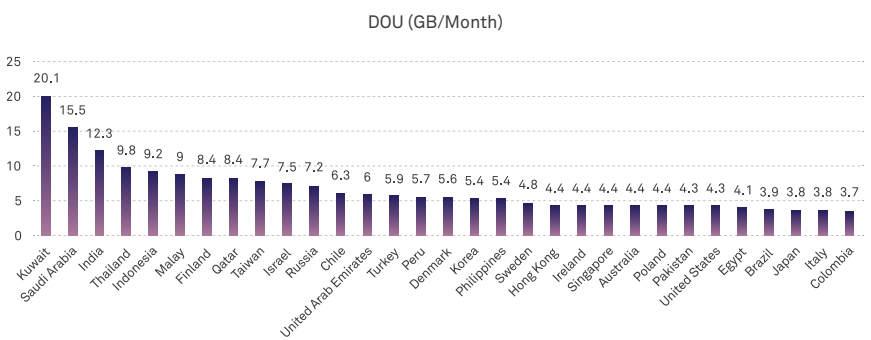
01 Executive Summary

The introduction of TM9 eliminates restrictions previously imposed by reference signal overhead on LTE multiple-antenna evolution and is a prerequisite for FDD beamforming and coordination features. TM9-based multiple-antenna technology significantly expands cell capacity and improves the experienced data rate and cell edge user experience.

TM9 multiple-antenna technology is a major LTE evolution feature, and similar technologies will be used in future 5G era network. The TM9 industry has quickly matured, and large-scale commercial deployments will occur in 2018.

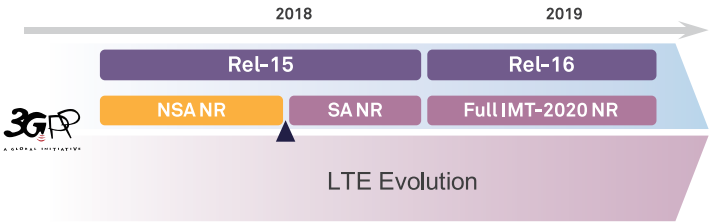
02 LTE Demands for Continuous Growth of Network Capacity

After deployment during nearly a decade, LTE now carries approximately 80% of the MBB traffic and has become the fundamental network to provide MBB services. Over the next decade, the number of LTE users will continue to significantly grow. GSMA estimates that there will be a net increase of around 3 billion LTE users by 2025. Meanwhile, traffic demand keeps growing from web browsing to HD video. The data of usage (DOU) in some countries already exceeds 10 GB/month.



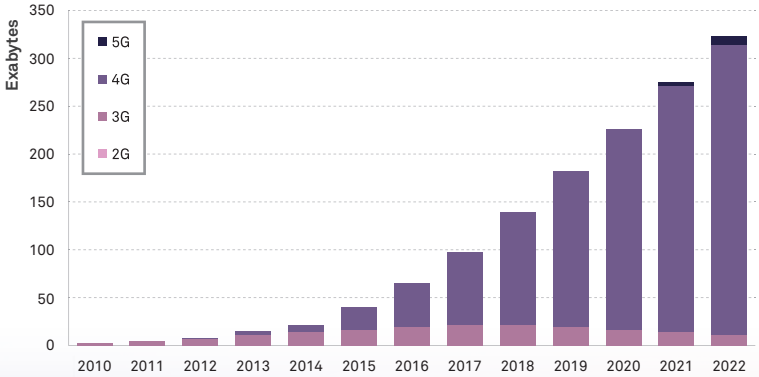
Source: Huawei

The 5G non-standalone (NSA) NR specifications have been frozen on December 21, 2017. These specifications define LTE as a basic bearer of 5G NSA. LTE technologies will evolve along with 5G NR to fulfill the requirements of 5G users for consistent service experience.



Benefiting from a wide network coverage, a huge base of users, and a large number of UE models, LTE will still remain the major network technology providing MBB services over the next decade. In addition, LTE traffic is expected to grow several folds. Hence, improving LTE capacity is critical.

Global Cellular Data Traffic by Network Generation



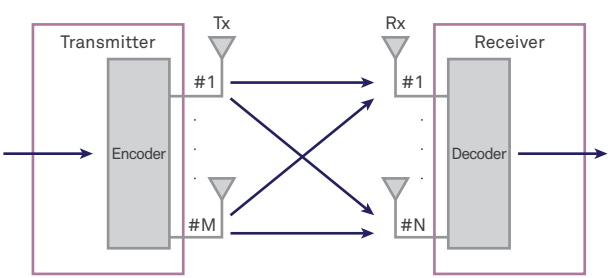
Source: Strategy Analytics

03 LTE Evolving towards Multiple-Antenna Technology for Improved Capacity

Various technologies and solutions have been developed to meet the growing demand for more capacity, such as bandwidth expansion and site densification. However, these approaches have limitations. For example, bandwidth cannot be expanded indefinitely, and site acquisition is getting more arduous. Multiple-antenna technology has been introduced to make a new way to ensure smooth capacity expansion.

Multiple-antenna technology, also known as MIMO (multiple-input multiple-output), uses multiple transmit and receive antennas and spatial multiplexing technology to significantly achieve coverage and capacity gains resulting in improved user experience without additional spectrum required.

The following figure shows an M×N MIMO system consisting of M transmit antennas and N receive antennas.



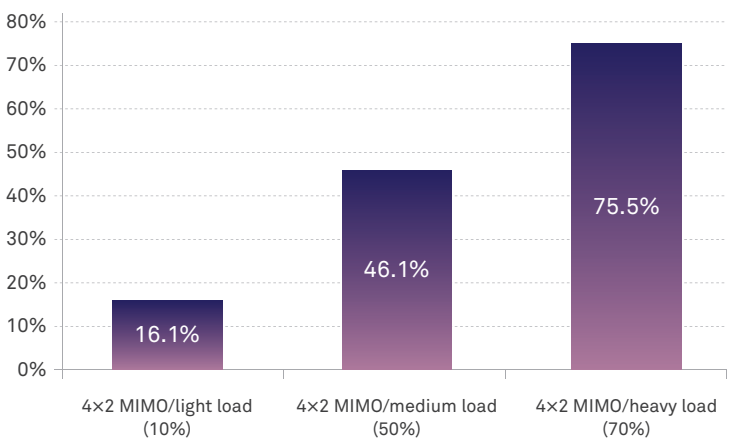
MxN MIMO

4-antenna technology has been introduced since the initial stage of LTE development. 4x4 MIMO supports simultaneous transmission of up to four data streams, almost doubling the peak rate of 2x2 MIMO.

Impressed by the large gains offered by 4T4R, there are already around 150 4T4R networks deployed globally up to now.

Even if UEs have only two antennas, which means maximum data stream number transferred to this UE cannot exceed two, 4x2 MIMO can still achieve a much higher average throughput than 2x2 MIMO. This is because a 4-antenna eNodeB obtains more accurate channel measurement results and feedback, and produces more spatial diversity gains.

Average perceived throughput gains offered by 4x2 MIMO in contrast with 2x2 MIMO



More antenna ports multiply the peak UE throughput and cell capacity. Multiple-antenna evolution has consequently become a major LTE evolution path.

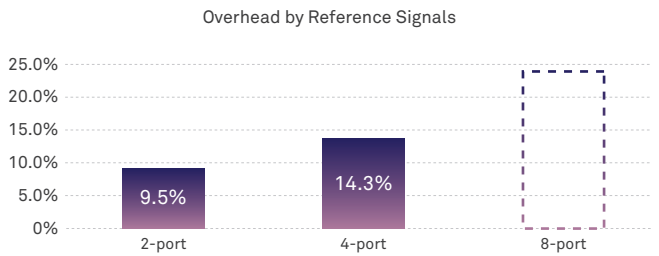
04 TM9 is Essential to Enable FDD Narrow Beam in Multiple-Antenna Network

As discussed previously, the increase of eNodeB antenna numbers significantly improves user data rates and capacity. However, eNodeBs compliant with 3GPP Releases older than Release 10 only support a maximum of four antennas due to the restriction of reference signals.

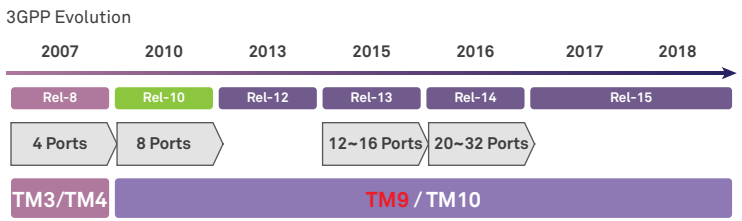
For 3GPP specifications before Release 10, eNodeBs only support one type of cell-level reference signals, the so-called "cell-specific reference signal (CRS)". CRS handles channel measurement, feedback, and data demodulation over the LTE air interface. CRS transmission causes extra overhead over air interface.The more air interface resources consumed by CRSs, the fewer air interface resources are available for data transmission.

Signals of different antennas are transmitted in different paths. Each antenna port requires a group of reference signals for accurate channel status measurement.

More antenna ports lead to more overhead in terms of air interface resources. For a 2-port antenna, CRSs consume 9.5% of air interface resources. This overhead increases to 14.3% for a 4-port transmission configuration. If the number of ports increases to eight, the overhead will be even worse, and this will annihilate the gain resulting from the additional ports. As a consequence, the maximum number of antenna ports supported by CRS is only four.

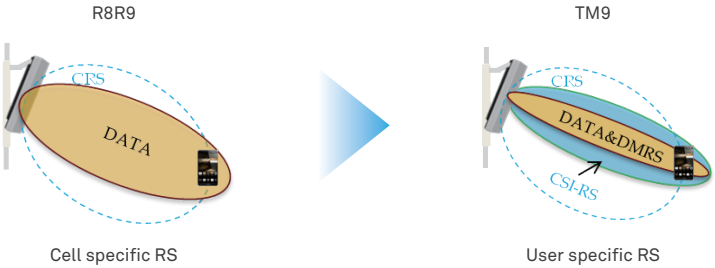


To address these limitations, 3GPP Release 10 introduced TM9 (Transmission Mode), a new reference signal design and channel feedback solution. TM9 eliminates reference signal limitations of multiple-antenna technology and allows for configurations with more than four antenna ports.



TM9 uses different reference signals for channel measurement/feedback and data demodulation. CSI reference signals (CSI-RSs) are used for channel measurement and feedback, while demodulation reference signals (DMRSs) are used for data demodulation. The advantage of this new reference signal design is that CSI-RSs consume fewer air interface resources to perform channel measurement/feedback, and that DMRSs are transmitted along with data and can be allocated on demand. In 3GPP Release 14, the maximum number of antenna ports has increased to 32.

In addition, different sets of CSI-RSs can be allocated to different UEs to form directional beams. CRSs are cell-level common reference signals and can be transmitted using only wide beams and cannot well support coordination features or beamforming. However, TM9 can allocate user-specific narrow beams by using CSI-RS and DMRS to enable beamforming and coordination features.



CRS (Release 8 & Release 9)	CSI-RS	DMRS
Channel measurement & demodulation	Channel measurement	Demodulation
Cell specific	User specific	User specific
More overhead	**Less overhead**	**More narrow beams**

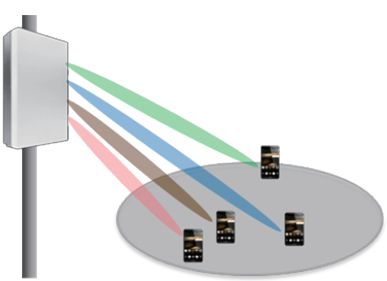
TM9-based multiple-antenna technology is a major trend in LTE evolution, and 5G era network also uses similar multiple antenna technology. TM9 introduces UE-level reference signals but still uses some CRSs complying with 3GPP Release 8 and Release 9, which ensures that UEs that are not TM9 capable are still compatible with TM9 networks.

05 Gains Offered by TM9

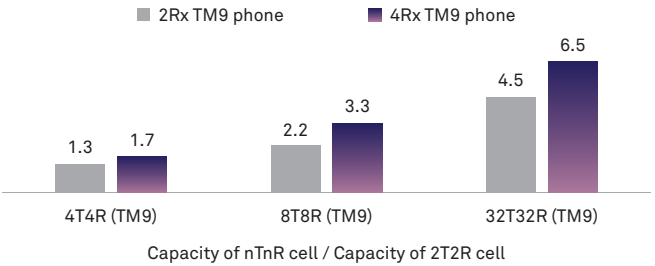
TM9 eliminates the restrictions usually imposed by the reference signal overhead associated to the addition of antenna ports and forms narrow beams to transmit UE-level reference signals, facilitating the wide development of LTE multiple-antenna technology.

5.1 TM9 MU-MIMO to Achieve 3 to 5 fold Capacity Gains

Multi-user MIMO (MU-MIMO) allows an eNodeB to serve multiple UEs using the same time-frequency resources, which significantly improves cell capacity. Without MU-MIMO, an LTE cell can serve only one UE per resource element, and time or frequency division multiplexing are required to serve multiple UEs. Due to the narrow beams introduced by TM9, the channels between users are more independent, which greatly reduces inter-UE interferences and ensures the performance of UEs who are transferring data in the same time and frequency resources.

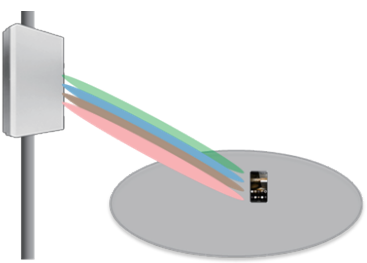


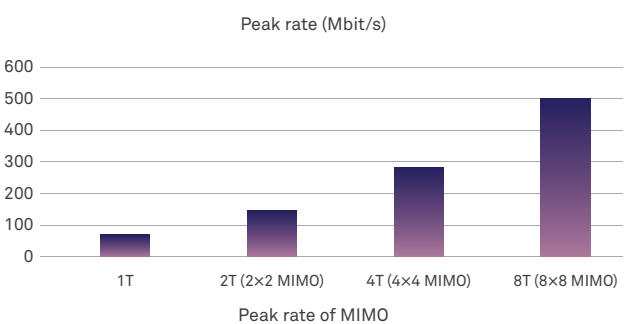
TM9-based MU-MIMO produces more important capacity gains than 2T2R. For example, if Rel-14 TM9 phones with 4 antennas are used, a 32T32R massive MIMO cell with TM9 enabled has up to 6.5-fold capacity increase over a 2T2R cell.



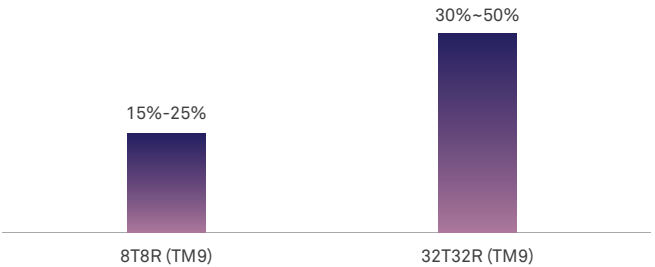
5.2 TM9 SU-MIMO to Improve User Experienced Data Rate by 30% to 50%

Single user MIMO (SU-MIMO) allows an eNodeB to transmit multiple data streams at the same time to one UE, which multiplies the UE peak rate. SU-MIMO allows for simultaneous transmission of eight data streams to each UE today. Currently, 8-antenna CPEs are available, and 4-antenna smartphones have become mainstream LTE devices.





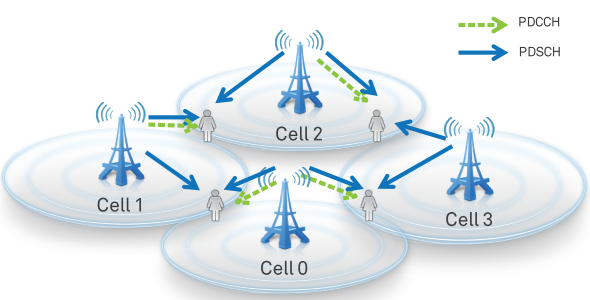
Even if the number of UE antennas is limited, a TM9-based, multiple-antenna network can achieve higher user experienced data rate due to more independent channels and a higher channel multiplexing rate.



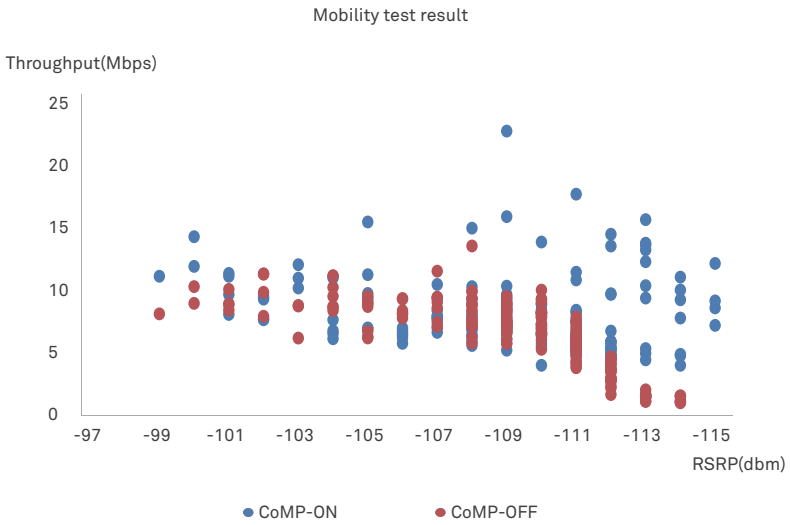
User experienced data rate gains offered by nTnR in contrast with 2T2R (based on 2Rx UE)

5.3 TM9 DL CoMP to Improve CEU Experience by 20% to 40%

One major concern of current LTE networks is cell-edge interference. The experience of a UE deteriorates greatly and services of the UE may even drop when the UE moves to an area where two cells overlap. Downlink Coordinated Multiple Points (DL CoMP) performs coordinated scheduling between adjacent cells to improve the cell edge user (CEU) experience in the overlapping areas. CoMP includes joint transmission and interference coordination. Joint transmission allows adjacent cells to send data to CEU simultaneously, which produces power and array gains. Interference coordination adjusts beams for UEs in adjacent cells to avoid interference to co-covered cell edge users.



In TM9, CEUs can receive the CSI-RS from adjacent cells, which can be used to precisely measure the channel status of coordinated data streams. TM9-based DL CoMP can improve the CEU throughput by 20% to 40%. The following figure shows DL CoMP tests results, and significant CEU gains offered by DL CoMP can be observed.



06 TM9 Industry Status

After years of evolution, the TM9 industry has matured. Major chip vendors, including Qualcomm and HiSilicon, have launched TM9-capable smartphone chipsets. More than 20 types of UEs are powered by these chipsets and are hardware ready for TM9. Owners of TM9 capable devices need only one click to upgrade their phones to activate TM9 features once vendors push TM9 software packages to their phones. The penetration rate of TM9 hardware ready phones in leading markets has already exceeded 40%.

TM9 has already been activated on several high-end UE models. All the major UE models to be launched in H2 2018 are expected to support TM9, and the penetration rate of TM9-capable UEs on live networks will exceed 20% by the end of 2018.

As TM9-capable UEs mature, more and more operators actively perform TM9 trials. More than 10 operators, including China Mobile and Verizon, have completed TM9 field tests. Up to 30 TM9 commercial networks are expected to be deployed this year. The wide application of TM9 on commercial networks will rapidly increase the TM9 UE penetration rate, facilitate the development in the multiple-antenna industry, and significantly improve LTE network capacity.

07 Appendix

7.1 Glossary

CEU	Cell Edge User
CRS	Cell-Specific Reference Signal
CSI	Channel State Information
CSI-RS	CSI Reference Signal
CQI	Channel Quality Indicator
DL	Downlink
DMRS	Demodulation Reference Signal
DOU	Data of Usage
FDD	Frequency Division Duplex
GB	Giga Bytes
HD	High Definition
IMT	International Mobile Telecommunications
LTE	Long Term Evolution (evolved air interface based on OFDMA)
MBB	Mobile Broadband
MHz	Mega Hertz
MIMO	Multiple Input Multiple Output
MU	Multi-User

NR	New Radio
NSA	Non-Standalone
RAN	Radio Access Network
RS	Reference Signal
SA	Standalone
SU	Single-User
TM	Transmission Mode
UE	User Equipment

7.2 Reference

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「2」 Advanced MIMO Boosts 4G and Gives Consumers a Taste of the Gigabit Experience, Guang Yang & Chris Taylor, Strategy Analytics

「3」 Global Mobile Trend 2017(Sep 2017), GSMA Intelligence

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