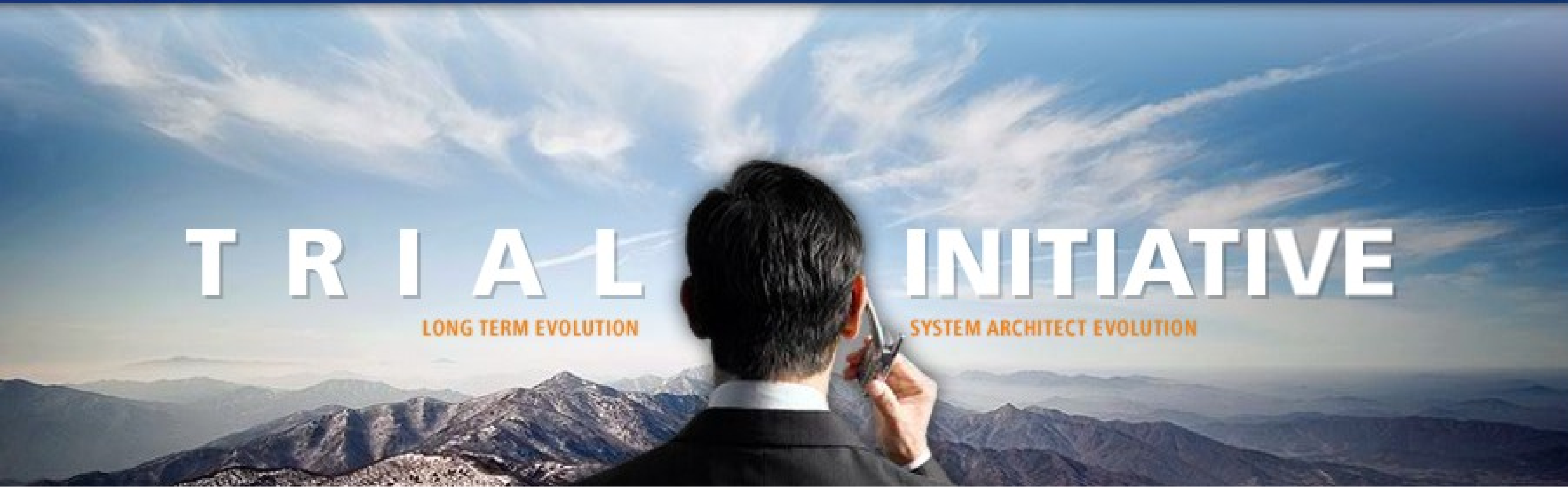


## *LTE/SAE Trial Initiative*

# Latest Results from the LSTI, Feb 2009

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Chairman LSTI Proof of Concept Group

www.lstiforum.org

# Contents

# The LTE /SAE Trial Initiative

- The LSTI is an open initiative driven by Vendors and Operators launched in May 2007
- Its objectives are to:
  - Drive industrialization of 3GPP LTE/SAE technology
  - Demonstrate LTE/SAE capabilities against 3GPP and NGMN requirements
  - Stimulate development of the LTE/SAE ecosystem

# LSTI Participants

## 23 LTE Equipment Vendors

Alcatel·Lucent | NOKIA Connecting People | ERICSSON TAKING YOU FORWARD | Nokia Siemens Networks | NORTEL | HUAWEI

LG Life's Good | MOTOROLA | SAMSUNG | Azimuth Wireless Test & Channel Emulation Experts | ZTE中兴 | QUALCOMM

ST-NXP Wireless | SIGNALION | Agilent | Panasonic ideas for life | ROHDE&SCHWARZ

NetHawk | STARENT NETWORKS | FUJITSU | NEC | freescale semiconductor | Tektronix Enabling Innovation

## 9 Operators

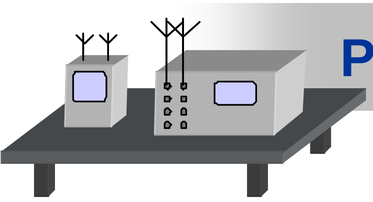
T··Mobile··· | NTT docomo | 中国移动通信 CHINA MOBILE 移动信息专家 | Telefonica

&ftgroup | vodafone | SFR | TELECOM ITALIA | SK telecom

**…representatives from across LTE's Global Ecosystem**

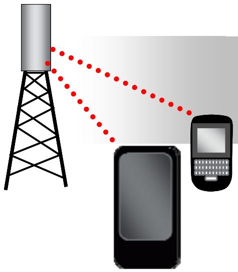
# LSTI Activities

*From* **Standardisation**…



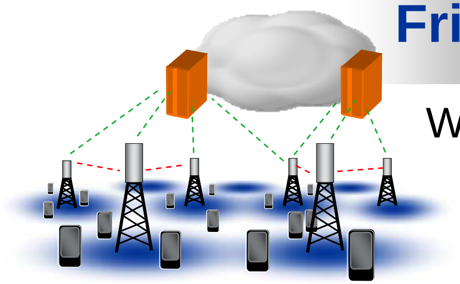
## Proof of Concept

Can the design be implemented? Are the performance targets achievable?



## Interoperability

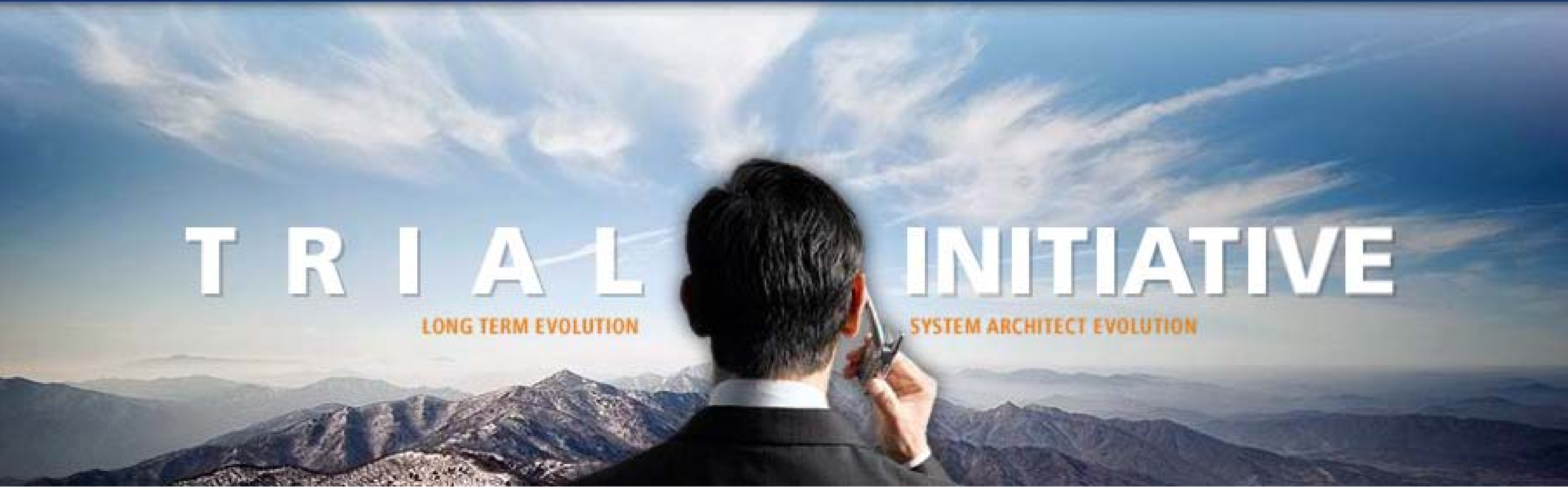
Does everyone have the same interpretation of the standard?



## Friendly Customer Trials

What can it deliver in near commercial conditions?

…*to* **Commercial Rollout**

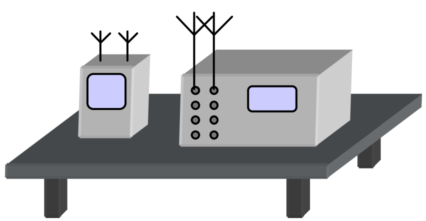


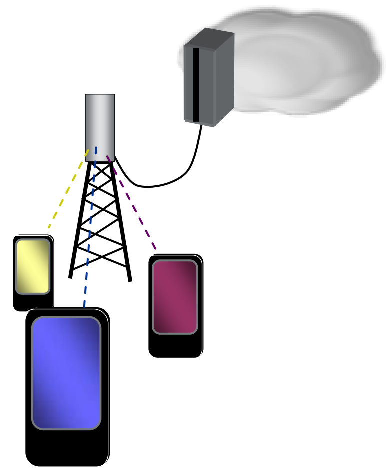

# Latest Results
# From the Proof of Concept Activity

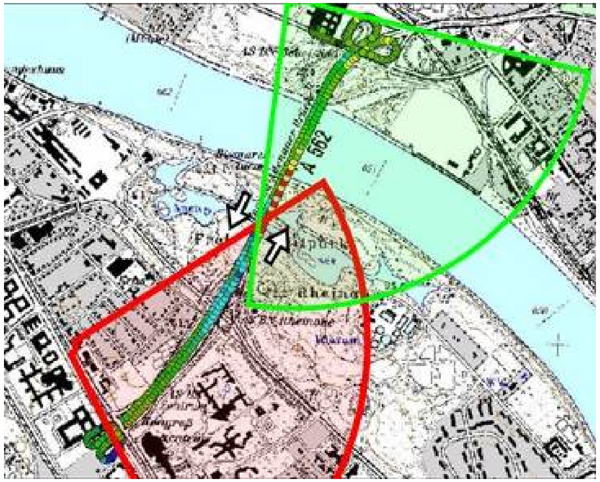
*Demonstrating that basic LTE/SAE functionality and performance are achievable with pre-standards proprietary equipment*

# “Proving The Concept” of LTE/SAE

**Lab tests** → **Multi User End-End** → **Multi Cell Live Air**







Peak data rates

Vehicle speeds

Multi user scheduling

QoS

Real world Data rates

VoIP

Radio latency

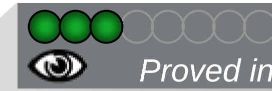
MIMO gains

Connection Setup time

Handover

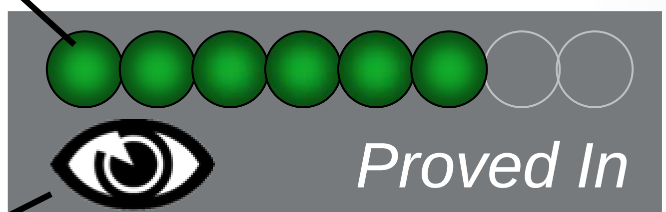
**Early testing focused on fundamental performance in ideal conditions…**

**…later tests required end to end architecture and real world scenarios**




# Proofpoint Status

Each filled circle represents one set of vendors tests which demonstrate the proofpoint is feasible




**Observed:** LSTI Operators visited the vendor’s test facilities and observed successful demonstration of the proofpoint

**A status indicator shows industry progress for each proofpoint**

# PoC Results

## Part 1) Data Rates

How much will you get?

*LTE is designed to deliver over 320 Mbps throughput*

*…But what can be achieved in practice?*

*And what data rates will users actually experience?*

## Part 2) Latency

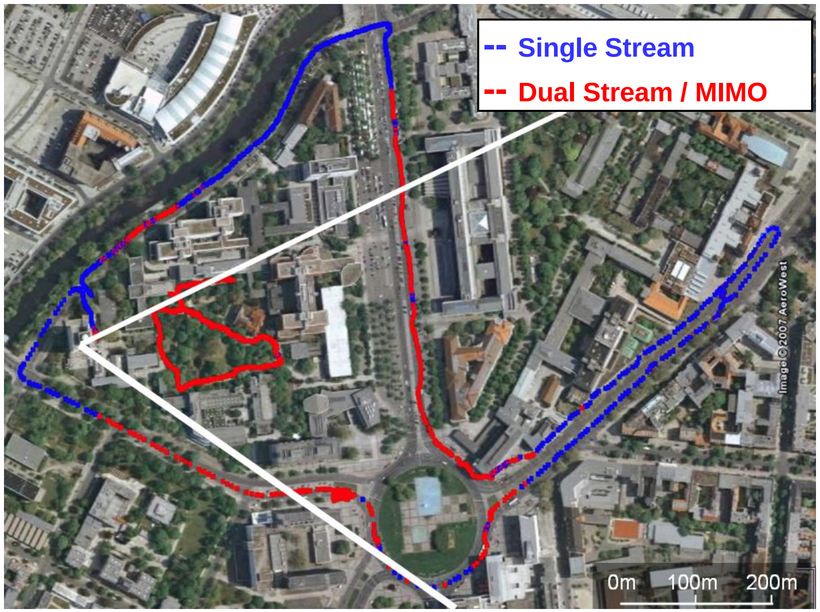
How quickly will you get it?

Proved in

# LTE working in the field

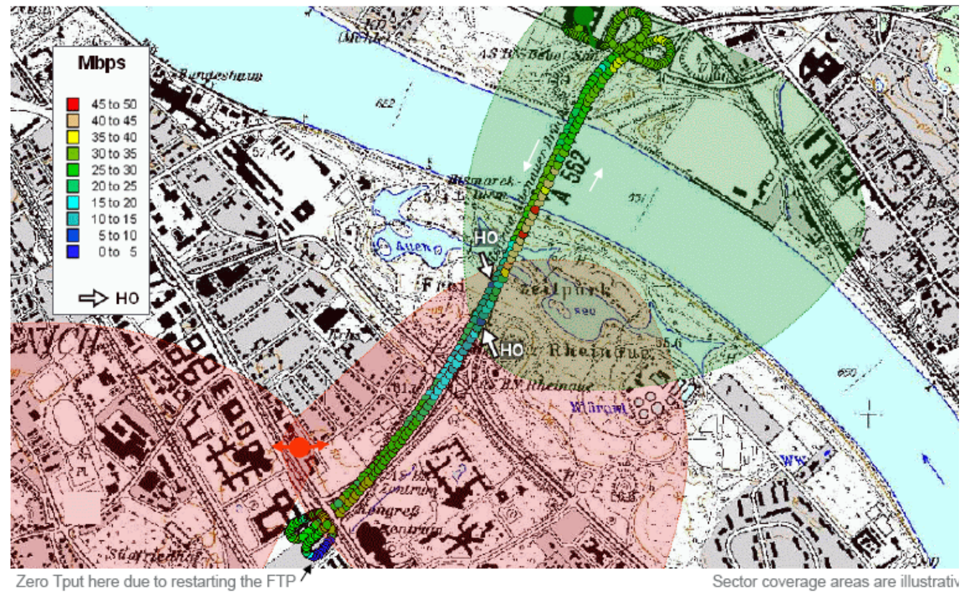
LTE has been proved working in the field both in single cell and multi cell scenarios

***Single Cell***

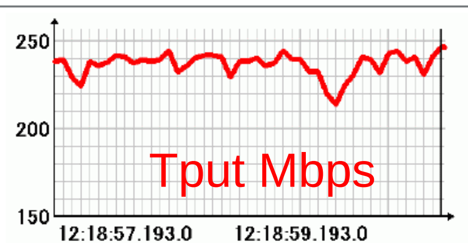



**MIMO working in the field**

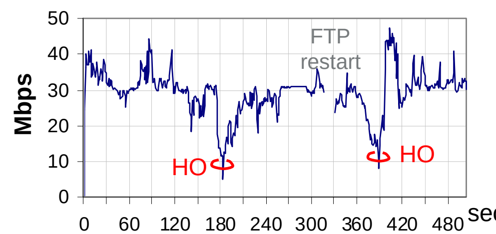
***Multi Cell***




**Handover at speeds up to 100km/h**



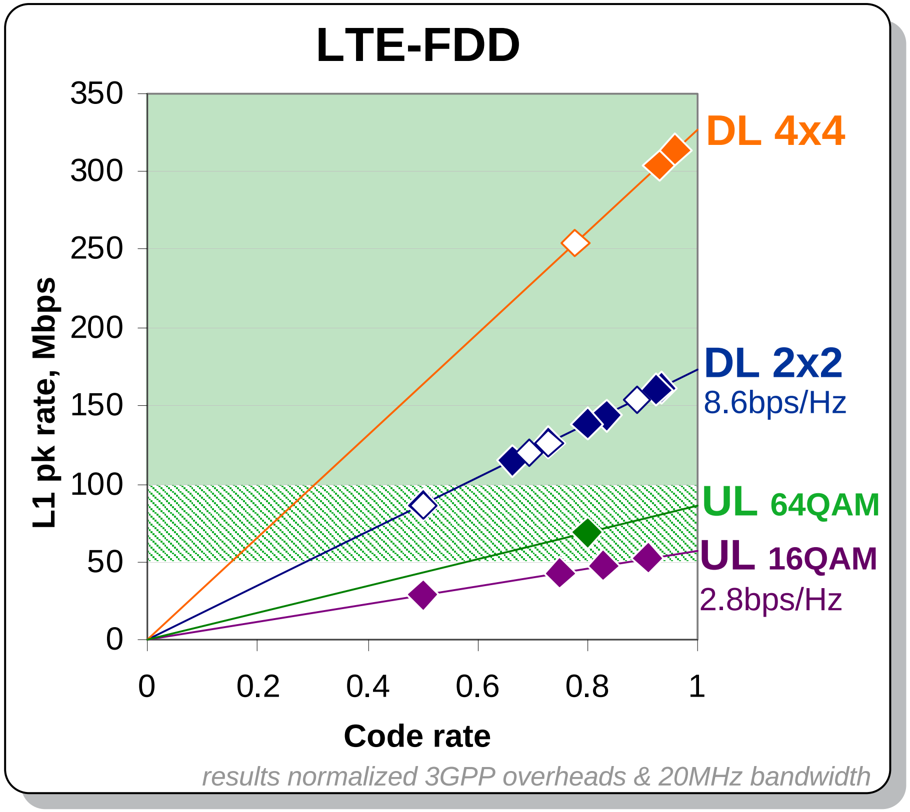

**246Mbps on a drive test with 4x4 MIMO**

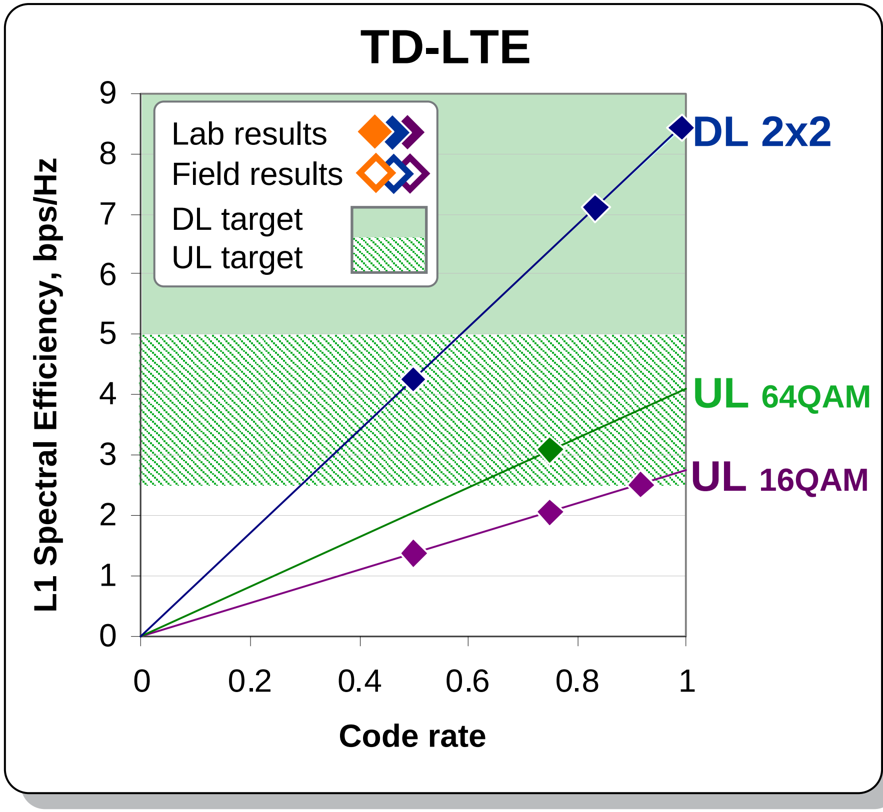



**48Mbps Tput on multicell drive test 2x2 MIMO**
10MHz BW

Proved in

# Peak Data Rates & Spectral Efficiency




Peak rates are the *top speed* of the system
…achieved in optimal signal conditions with a single user in the cell

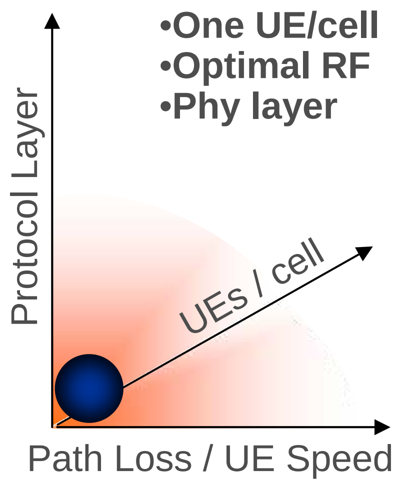
Requirements are 100Mbps or 5bps/Hz for DL, and 50Mbps or 2.5bps/Hz for UL

Measured Peak rates in lab and field meet the requirements

# …So Will All Users Experience >100Mbps?

- Peak rate requirements apply to corner point conditions which can be verified by simulation or lab testing
- Actual rates that users experience will be impacted by:

**Pk Rates Represent Corner Conditions**



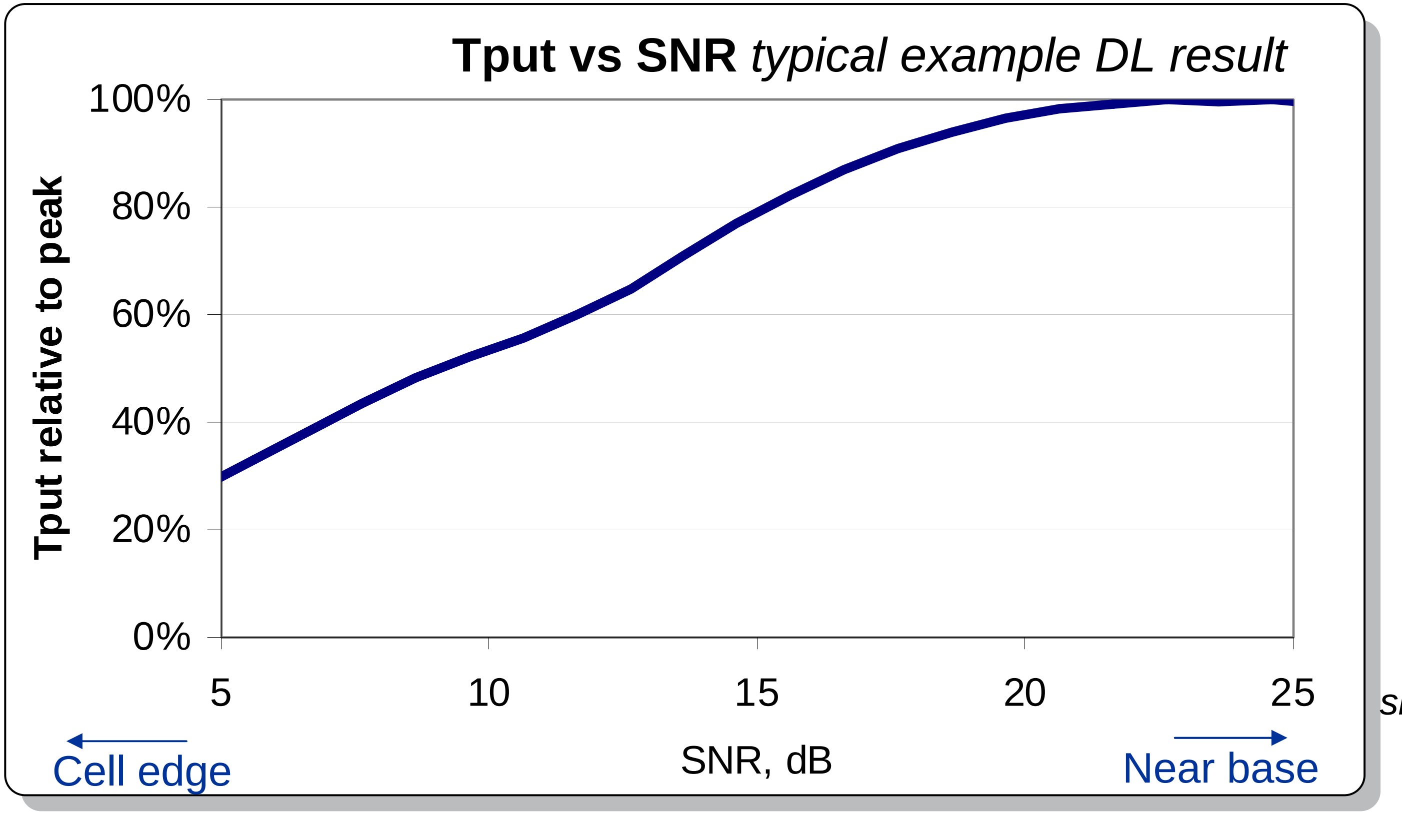

**1) RF conditions & UE speed**
Peak rates represent optimal conditions, lower rates are experienced towards the cell edge and when the UE is moving at high speed

**2) Multiple users in the cell**
UE data rates will be lower when sharing the cell with others

**3) Application Overheads**
Peak rate requirements apply to Physical layer. There will be overheads when considering data transfer between applications

- Impacts to UE rates are analysed in the following slides….

# **Radio Conditions** – Signal quality



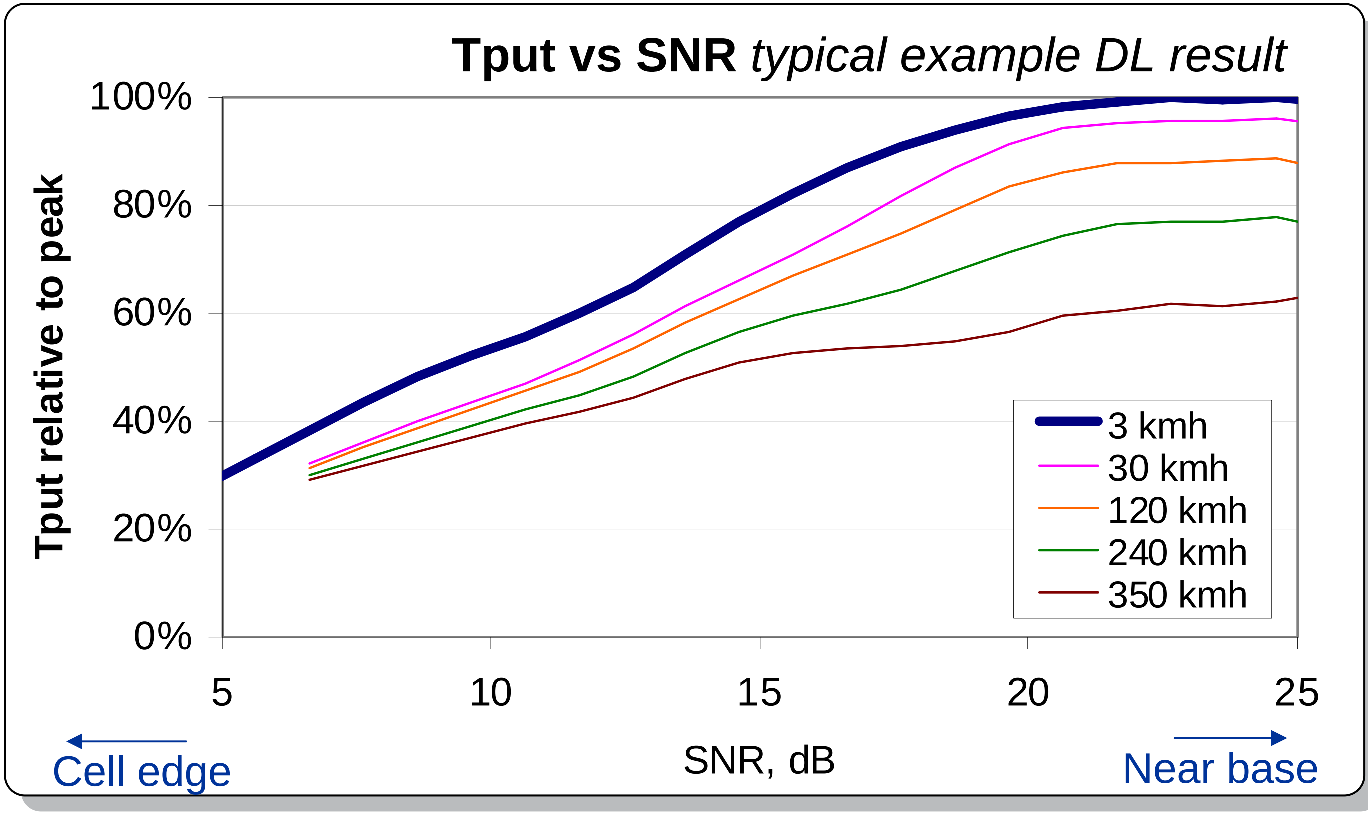

*Example results shown, similar behaviour observed for SM MIMO, SIMO and SFBC and UL SIMO*

Peak rates are achieved with high signal quality near the base station

Tput is lower towards the cell edge

Proved-in

# **Radio Conditions** – UE Speed




*Example results shown, similar behaviour observed for SM MIMO, SIMO and SFBC and UL SIMO*

Resiliency of LTE prototypes to high user speeds is tested in the lab

Initial results demonstrate support of up to 350km/h

Little impact to throughput is seen at speeds up to 120km/h

Proved in

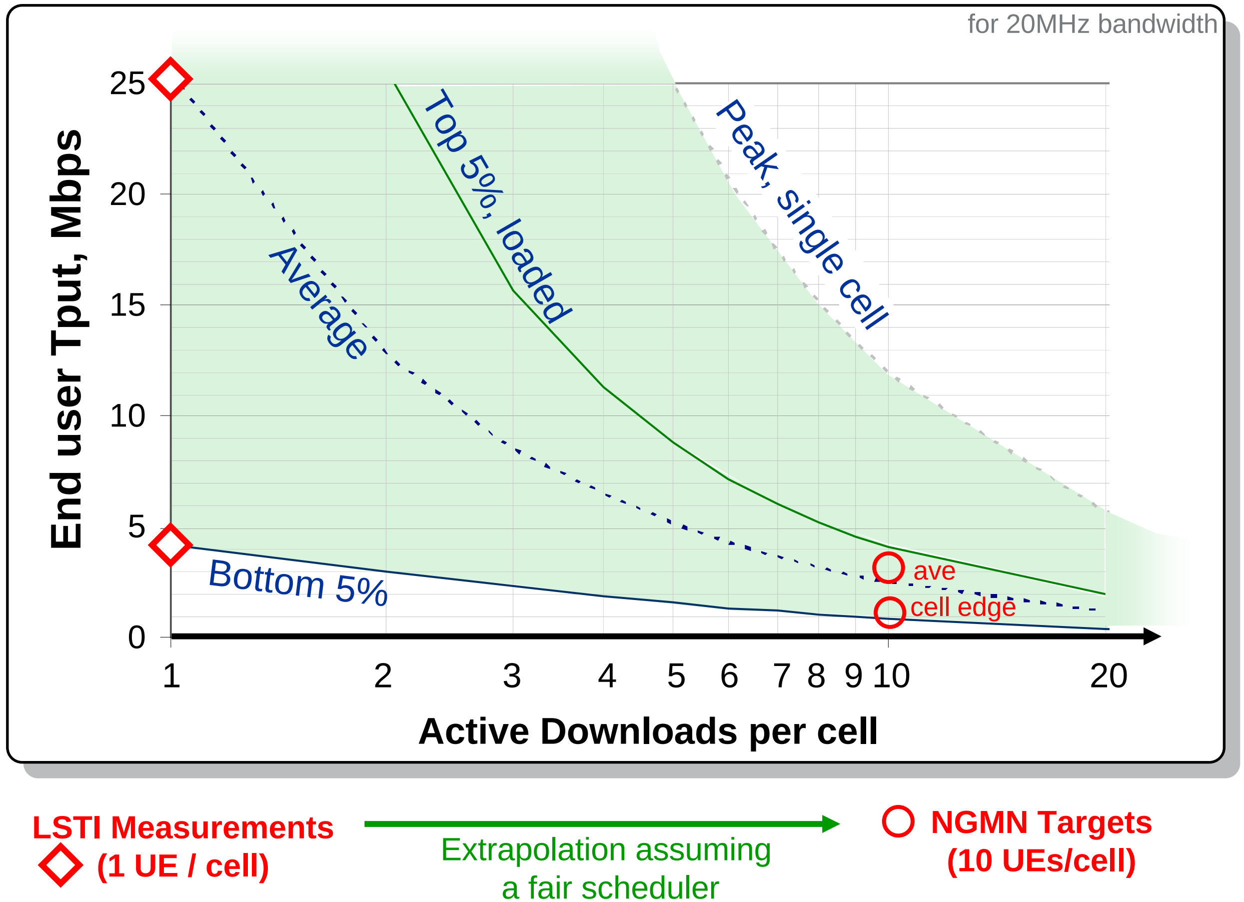
# Predicted End User Data Rates

Consolidated measurements show cell edge and average user Tputs with 'busy hour' interference levels and 1 UE/cell,

The green area is an extrapolation showing the variation of user data rates…

..from the best case
*Peak rate in an isolated cell*

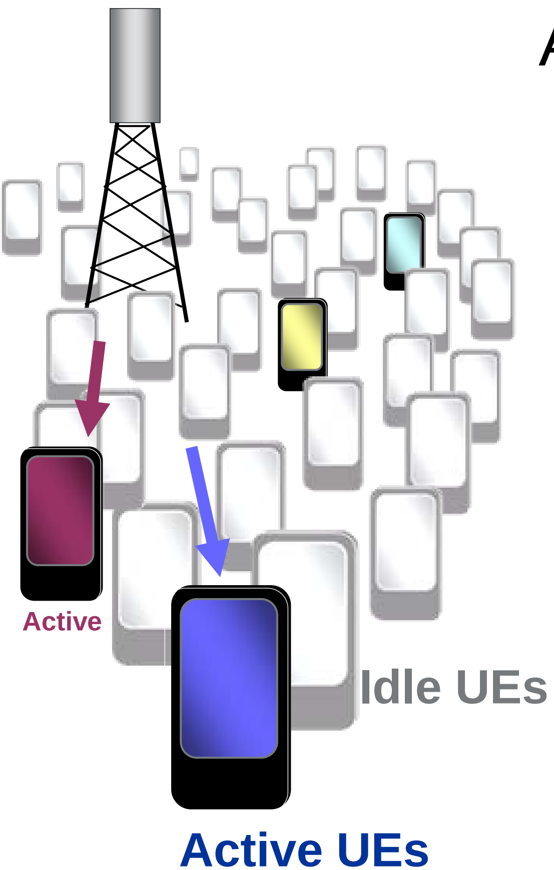
..to the worst case
*Bottom 5%-ile in busy hour*



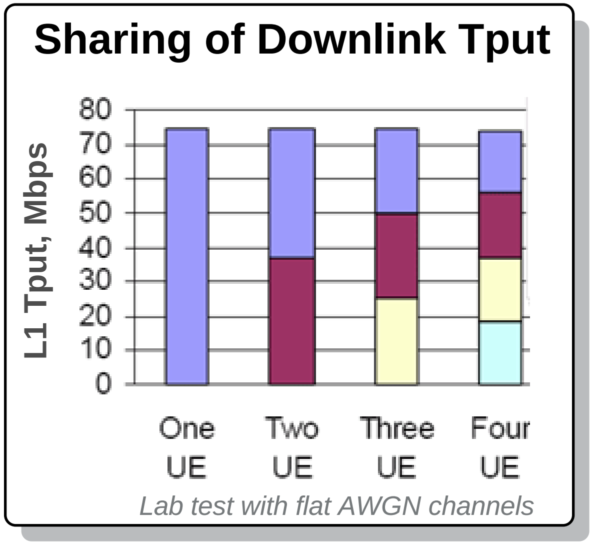

**Predicted end-user Tputs based on LSTI lab measurements align with NGMN Targets for 'cell edge' and average Tput**

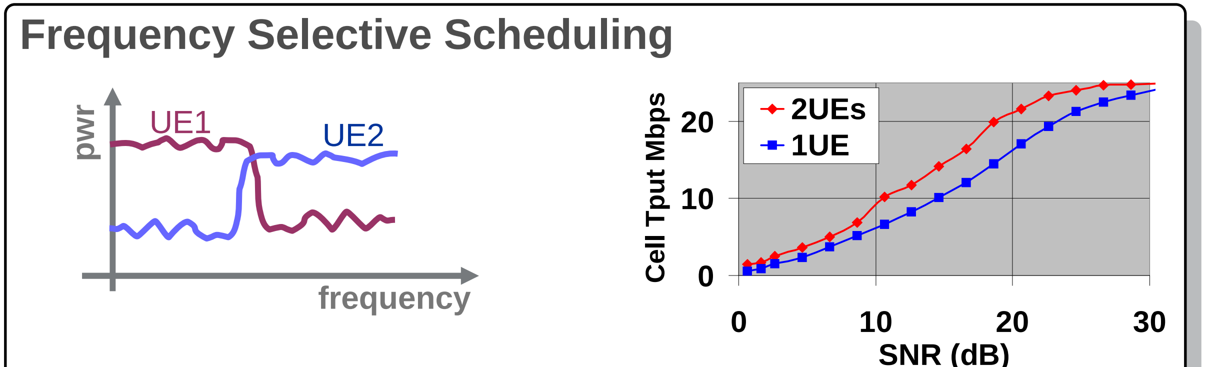
Proved-in

# **Multiple Users per Cell** - Downlink




At any given instant, the cell's spectral resource is shared between all active users



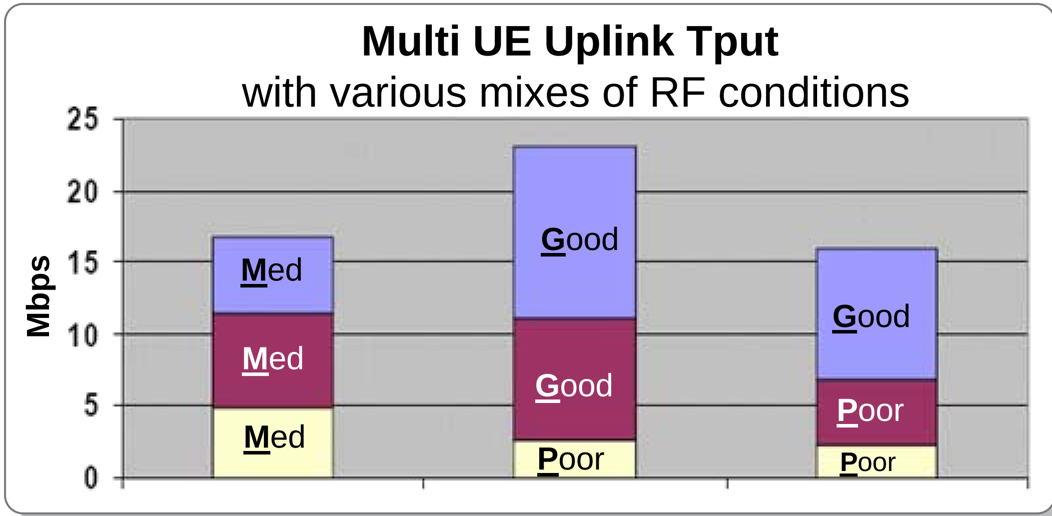




The scheduler can exploit different frequency responses of each UE's channel, to increase cell Tput

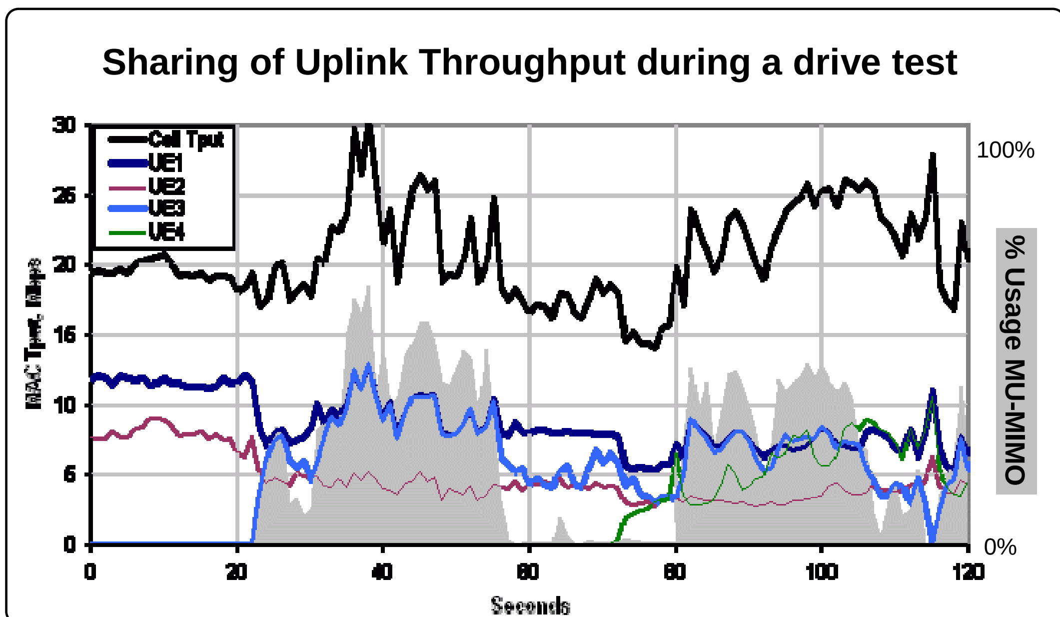
# **Multiple Users per Cell** - Uplink

*Proved-in*

Cell Tput depends on the mix of RF conditions for the active UEs



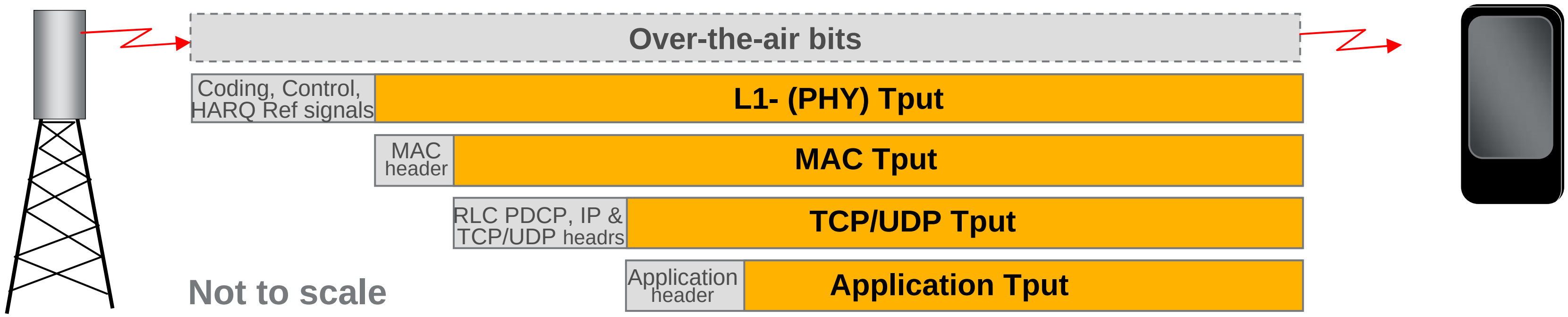


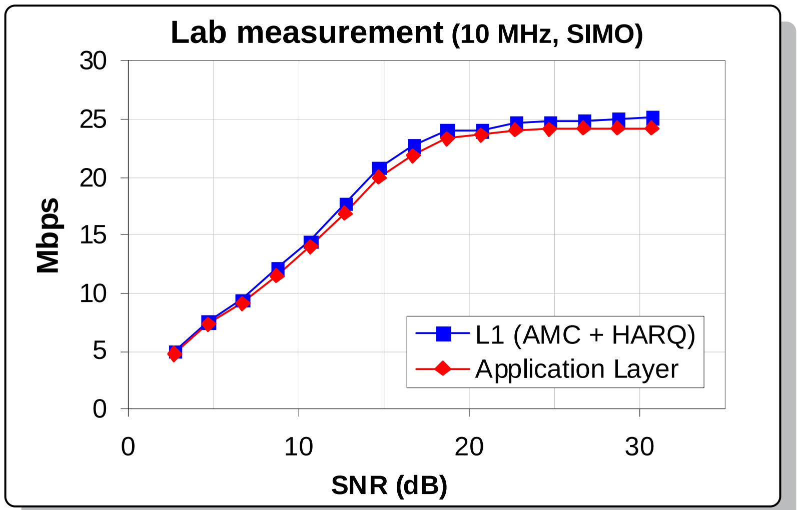


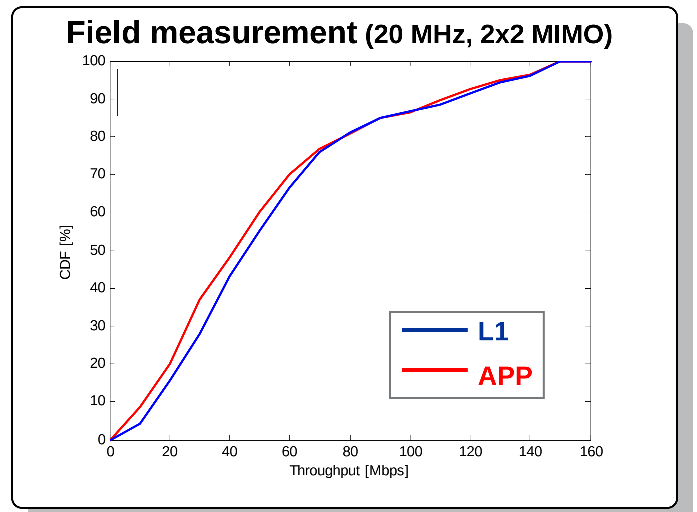

The LTE Uplink has Multi-User MIMO, which pairs-up UEs to share the same UL resource to increase cell Tput

Proved In

# Throughput at the Application Layer



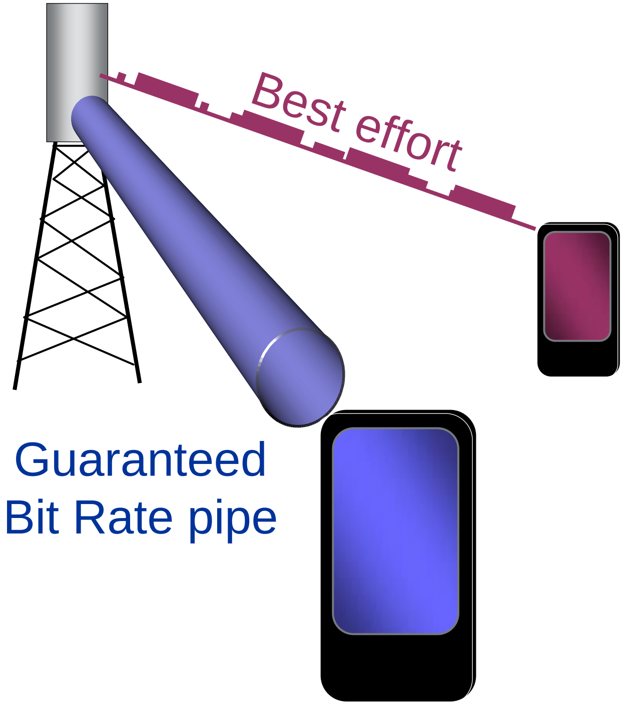

Throughput requirements are specified at L1 (Physical Layer)

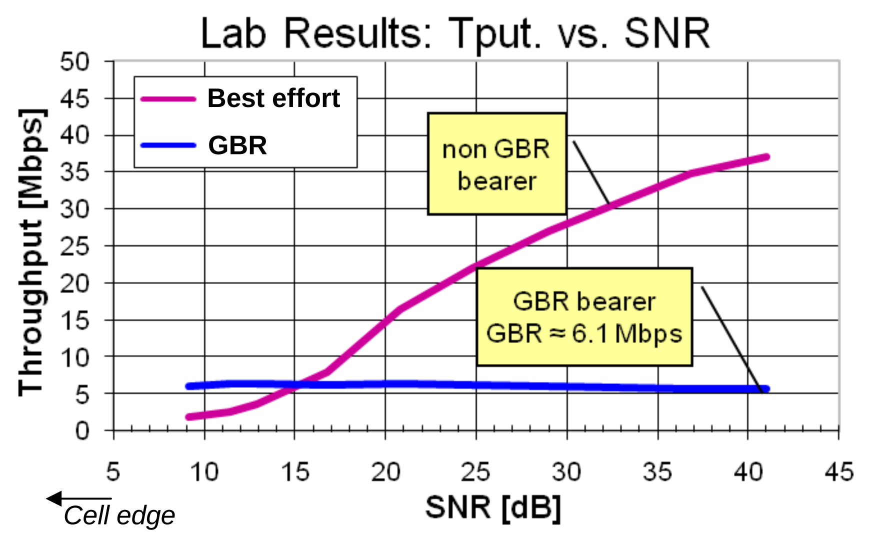
Measurements show the difference between L1 & Application to be small for large packets (e.g. File Transfer)

Note IP packet size affects the amount of protocol overhead

Proved in

# Guaranteed Bit Rate Support




*The GBR user is allocated resource to maintain their desired rate. The best effort user is given the rest*

Since end user data rates can vary with radio conditions and network loading, LTE has to provide Guaranteed Bit Rate (GBR) links, in order to support streaming services such as IPTV or internet radio

Several vendors have demonstrated that constant bit rates can be maintained independently of signal quality and other traffic on the cell

# PoC Results



**Part 1) Data Rates**
How much will you get?

**Part 2) Latency**
How quickly will you get it?

*To provide an ‘always on’ experience, LTE/SAE requires low delays for both user data and control of resources*

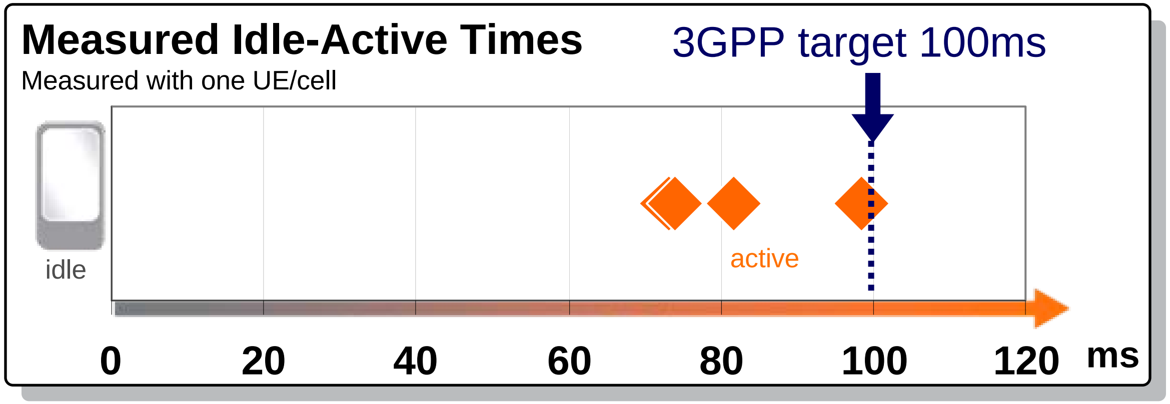



Stopwatch by P.Neal www.PNeal.com

Proved in

# Control-Plane Latency: Idle to Active time

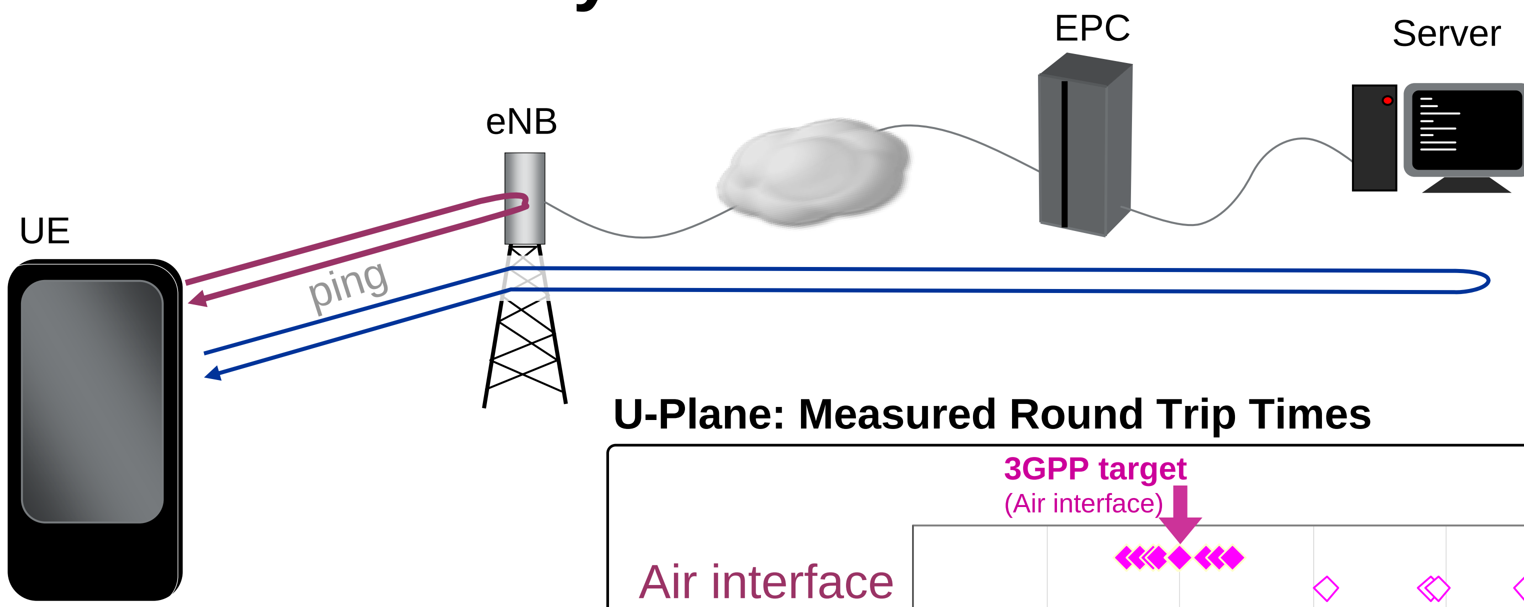

- To provide many users with an 'always-on' experience, LTE is designed with a low idle to active transition time
- All UEs sit in an idle state when there is no data to transfer – but can be activated quickly when they need to communicate



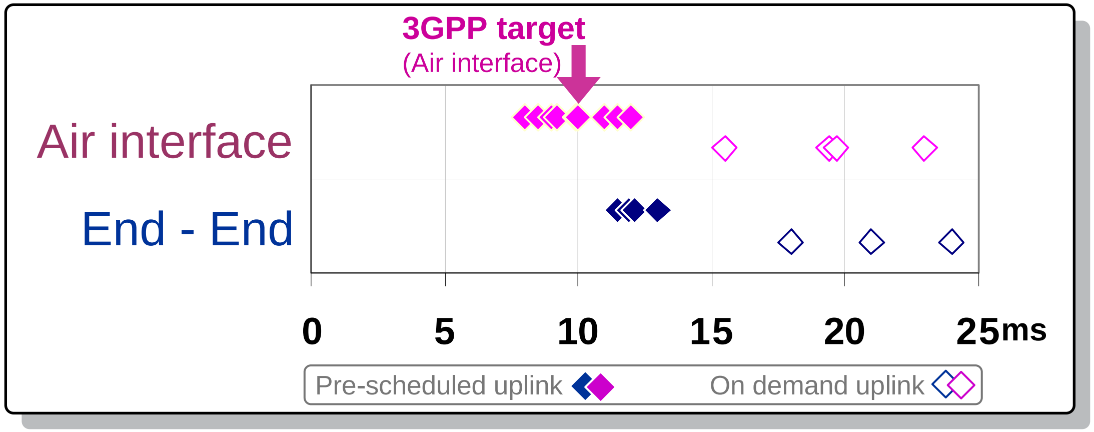

Measured idle to active times meet the 100ms requirement

Proved in

# User-Plane Latency




**U-Plane: Measured Round Trip Times**



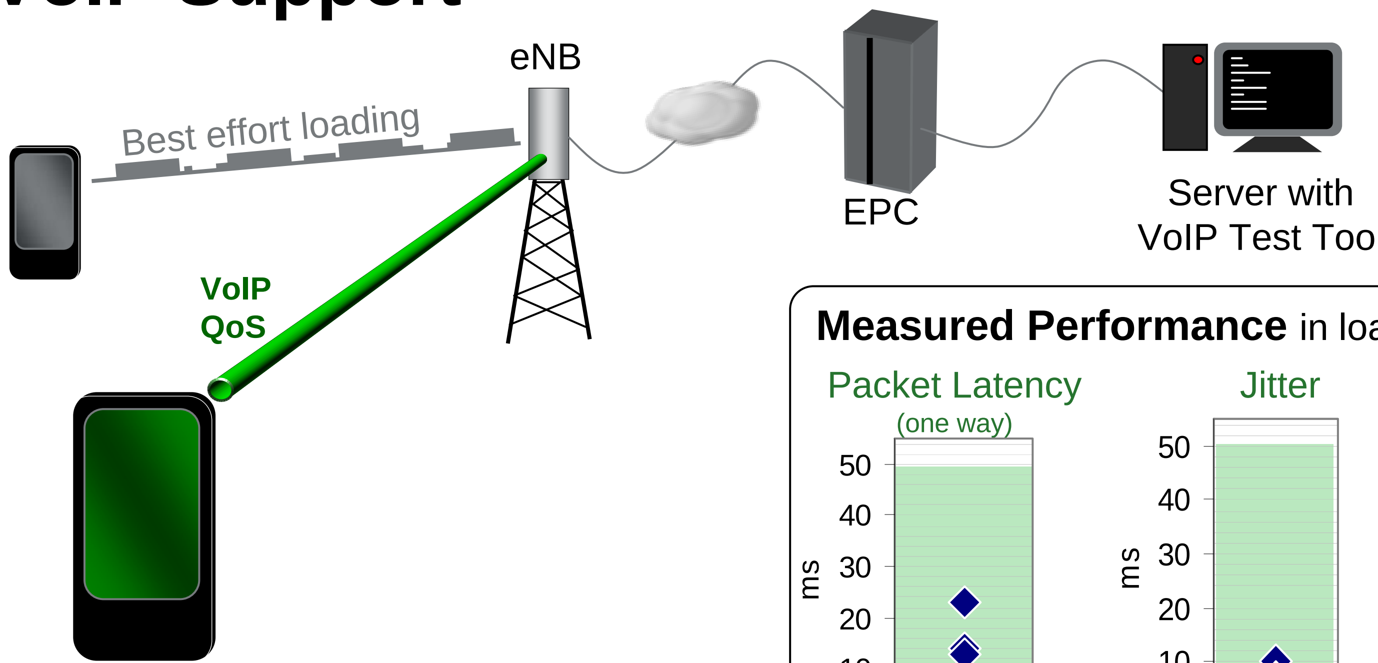

Low user-Plane latency is essential for delivering interactive services, like gaming and VoIP

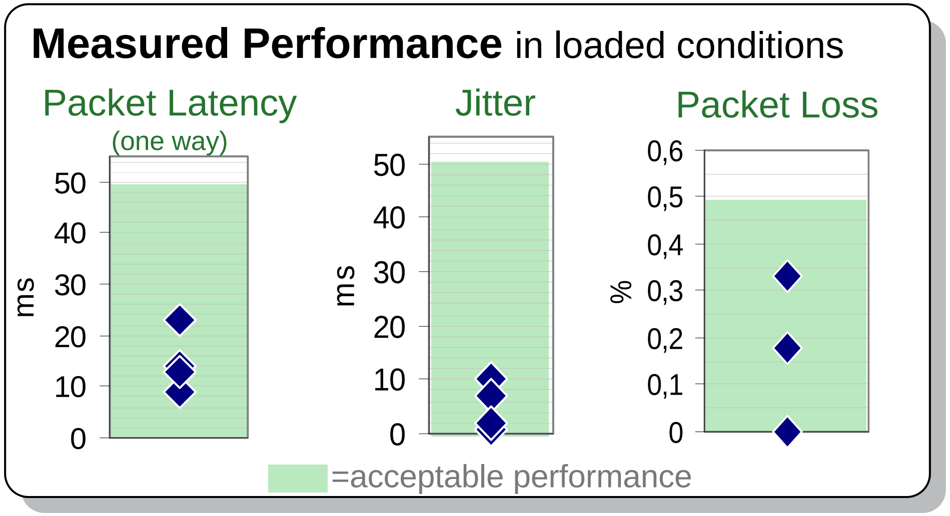
Measured round trip times with a pre-scheduled uplink meet the 3GPP target of 10ms

Unpredictable traffic requires an on-demand uplink, E2E round trips times are under 25ms

Proved in

# VoIP Support




As with data rates, latency can be impacted by signal conditions and loading

Tests in ideal lab conditions have demonstrated that LTE/SAE is capable of providing IP connectivity with sufficient latency, jitter and packet loss performance to support good quality VoIP, even in the presence of other traffic.

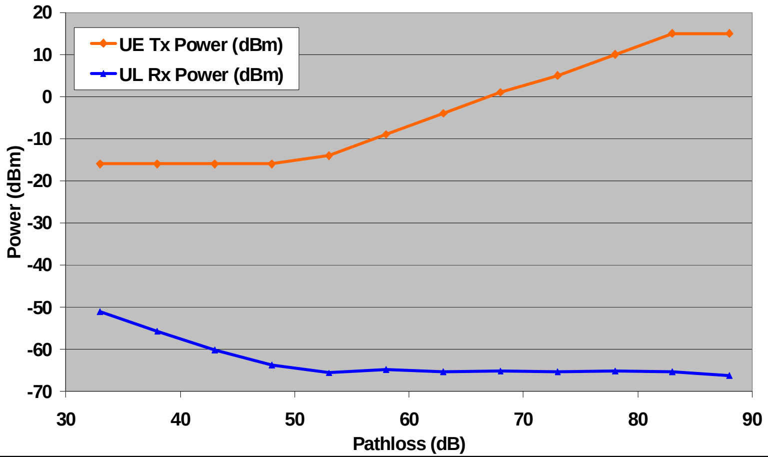
Operators observed good quality VoIP maintained in live air drive tests with handover

Proved in

# Uplink Transmit Power Control

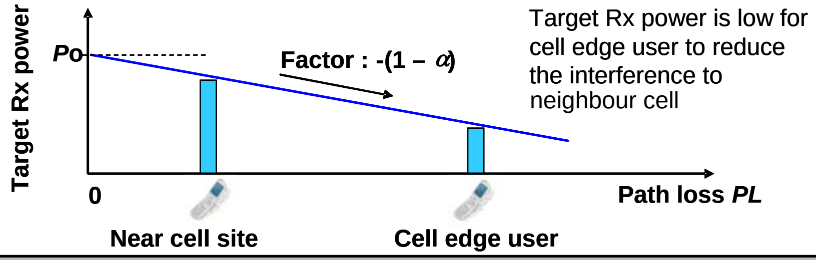
## **Normal** Power Control

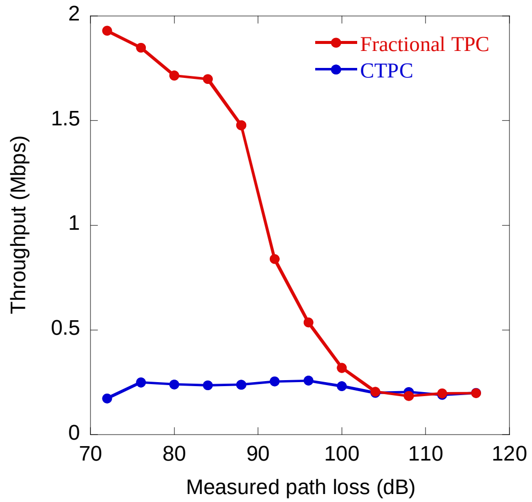
Three companies demonstrated open and closed-loop TPC working in the lab or field. Results shows TPC maintaining desired UL received power at eNB to compensate for path loss.




## **Fractional** Power Control

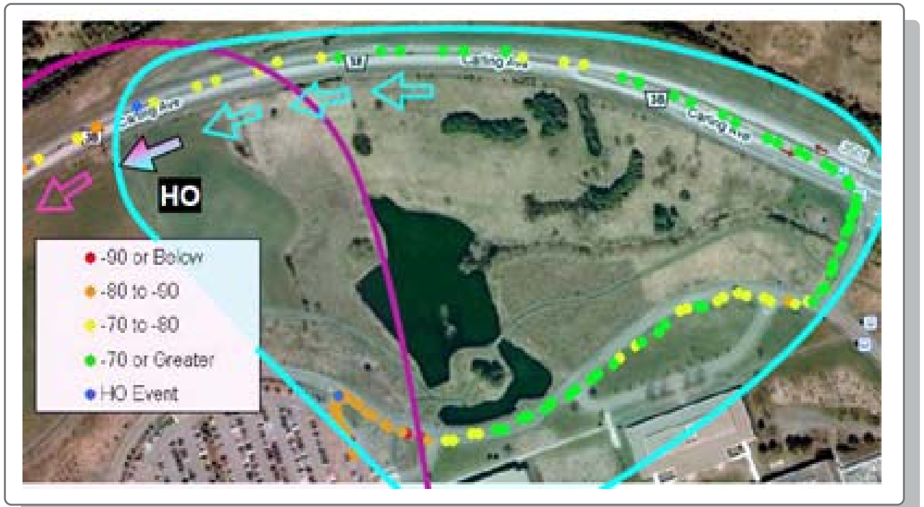
An initial result shows Fractional TPC increases Tput near the base station with only a small increases in interference to other cells

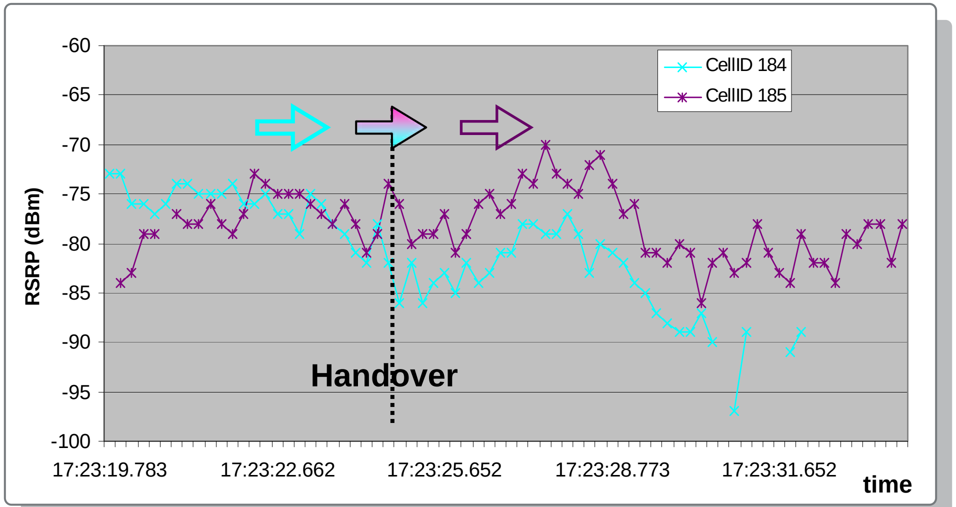


Proved in

# Measurement Functionality




The UE must perform measurements and report them back to the eNB, for use in Radio Resource Management decisions.

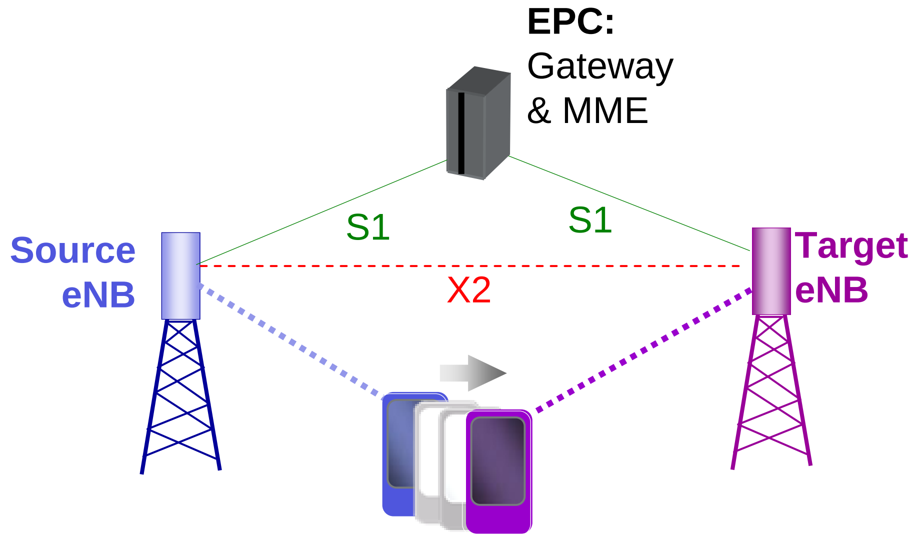
The above example shows UE measurements of pilot signals from two cells. The eNB performs a handover once the new cell is consistently stronger.

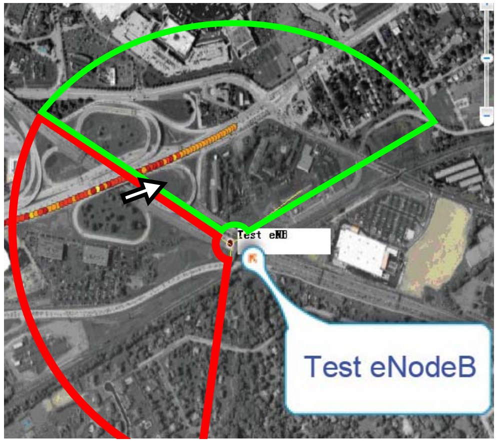
UE Measurements have also be shown to enable uplink power control, frequency selective scheduling and link adaptation

Proved in

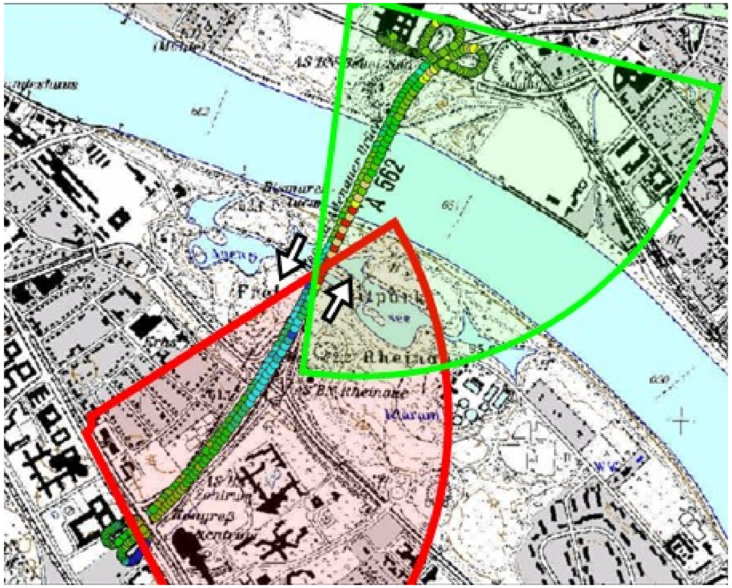
# Handover

- Inter-eNB and intra-eNB handovers demonstrated in the lab and field at up to 120 km/h
- Data interruption times under 50ms achieved, meeting NGMN's 'real time service' requirement
- Both S1 and X2-assisted handovers demonstrated
  - X2 Improves handover performance and reduces loading on MME




Intra eNB handover



Inter eNB handover

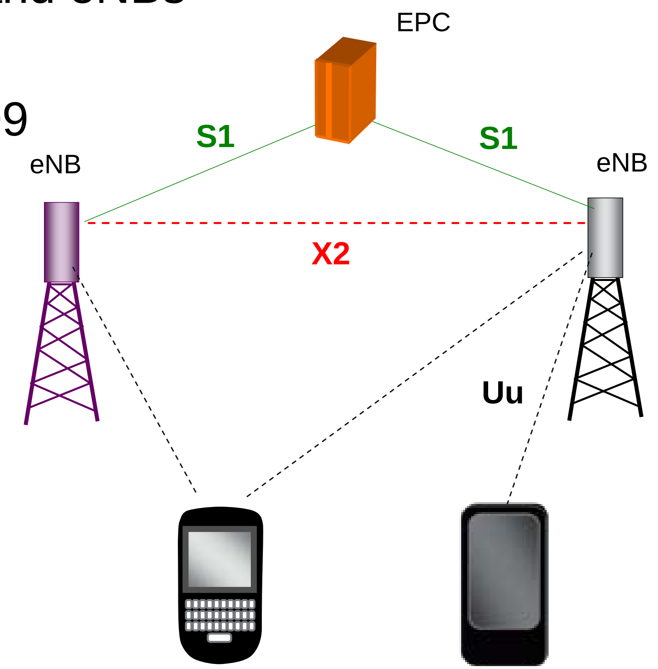
# Summary of PoC Results

- Over 80 sets of tests from 8 vendors consolidated into 15 proofpoints, demonstrating feasibility of key LTE/SAE functionality and performance:
  - 3GPP and NGMN targets for peak data rates and minimum latency are achievable for both FDD and TDD variants
  - ‘Real world’ performance results are also given, helping operators understand what can be offered to end users
  - QoS has been demonstrated to provide the consistent data rates and latency needed to support services like VoIP
  - Benefits of MIMO, Frequency Selective Scheduling and fractional power control technologies are shown
  - Demonstration of key functionality like Handover and UE measurement reporting shows the maturity of developments

**LTE/SAE does exactly what it says on the box**

# Interoperability Testing (IOT)

- **Successful IOT shows that everybody has the same interpretation of the standard, implying a level of maturity**
- **LSTI agrees and recommends a core set of features for interoperability testing on the LTE/SAE interfaces**
- **First phase: IODT** (D=Development)
  - Focus on the Air interface: IOT between UEs and eNBs
  - Feature set and standards baselines agreed
  - Testing underway, reporting during Q2-Q4 2009
- **Second phase: IOT**
  - Extra features and multiple partners for the Air Interface
  - S1 and X2 testing, requiring multiple RAN and EPC vendors
  - Expected to complete mid 2010

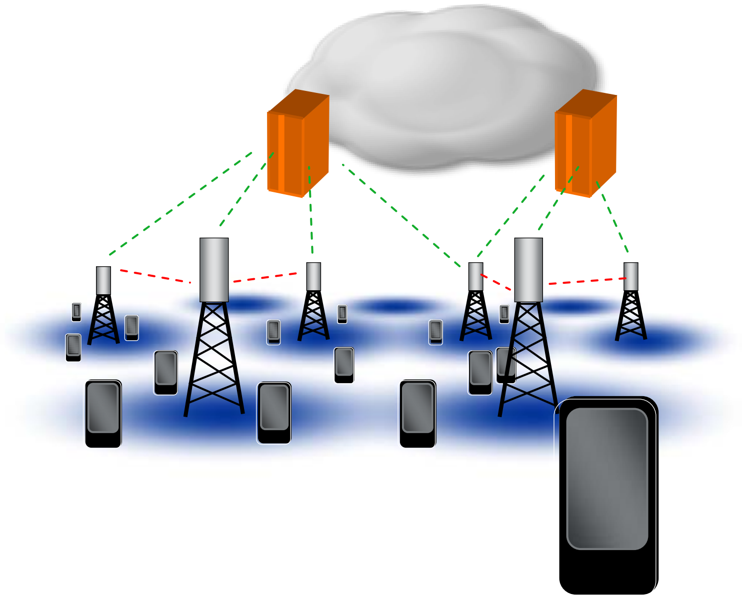


# Friendly Customer Trials

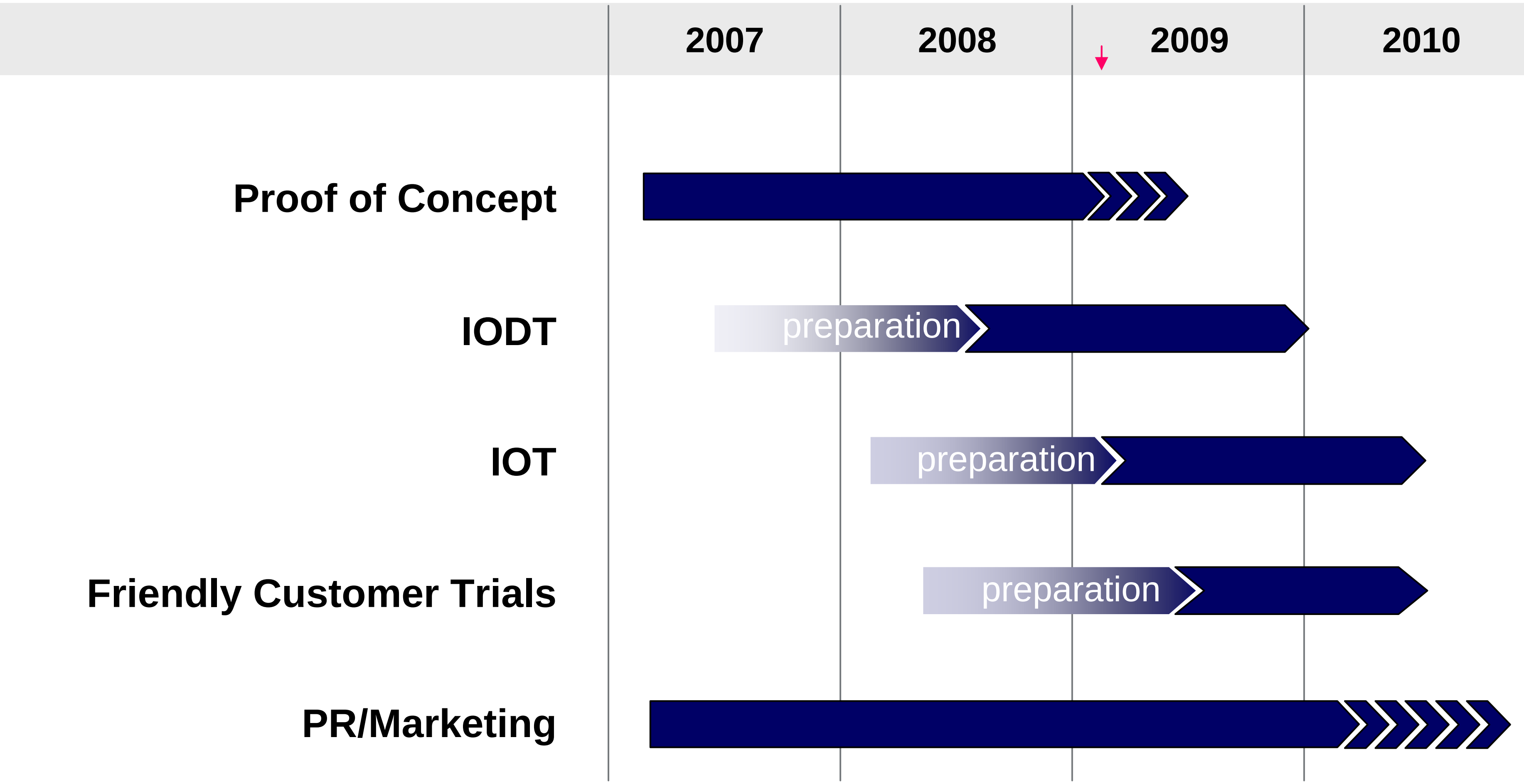
- **The friendly user trial phase enables Vendors and Operators to prepare for deployment and commercial launch**
  - Visualize LTE capabilities and advantages in nearly commercial conditions with test applications provided by vendors and 3rd parties
- **Status**
  - Trial test cases based on NGMN field trial requirements have been drafted and are under peer review
  - Content and timing of phases agreed:

    1) Early testing of Radio access systems – by end 2009

    2) Integration of EPC to enable End-to-end testing – by mid 2010



# LSTI Activity Timing



# In Summary,
# **The LTE/SAE Trial Initiative….**

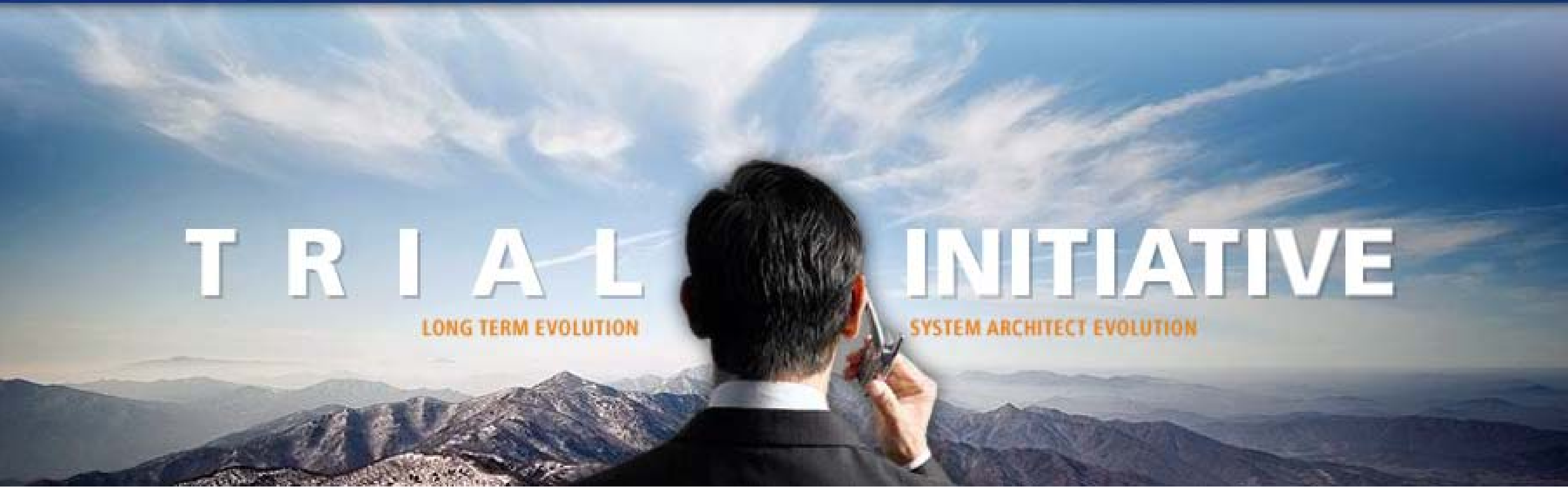
…is an open initiative of vendors and operators working together to accelerate the development of a global ecosystem for LTE

…provides cross-industry co-ordination of prototyping, interoperability testing and field trials

## The Proof of Concept Activity…

…has shown that it is feasible to make LTE/SAE equipment that can meet industry targets for peak performance

…is also revealing the performance that operators will be able to offer to end users in real world conditions




# Thank You

LSTi
LTE/SAE Trial Initiative

www.lstiforum.org