Revision History

Revision	Date	Description
A	July 2016	Initial release

Agenda

Objectives and Scenarios

Objectives and Value

OBJECTIVES

- Compare DL average user throughput when doubling the spectrum (Competitor) versus adding sites (3UK) in different network loaded scenarios

- Perform LTE simulations using QUEST simulator of existing macro network cluster (7 sites) around Maidenhead HQ with current spectrum configurations (baseline): competitor with 20 MHz vs 3UK with 10 MHz

- Perform LTE simulations to investigate benefits of site densification in 3UK constellation in order to achieve same target throughput generated in competitor spectrum constellation

VALUE

- Investigate solutions for 3UK for enhancing the capacity and better compete with other operators

- Assess DL average throughput in both 3UK and competitor spectrum constellation

- Forecast the number of sites needed for 3UK operator to match average user throughput of competitor network

- Determine tradeoff between spectrum and densification for achieving target user throughput

Process Methodology

Process to perform QUEST throughput performance analysis simulation based on RF predictions

NPT Prediction

- Creation of cluster Path Loss Matrices with Macro Cells from Network Planning Tool (Baseline for two spectrum constellations and scenarios with added sites)

- Import of Users Distribution (Low, Medium and High Loaded Scenarios)

- Import of Traffic Distribution (Video users and test full buffer user)

QUEST Simulation

- Identification of Constellations (3UK vs. competitor) and Scenarios (Low, Medium, and High load)

- Configuration of LTE related parameters

- Configuration of simulation related parameters

- Baseline Simulations and Output Analysis

- Repeat Simulations with increased number of sites & Output Analysis

Simulation Scenarios – Baselines and Site Densification

3UK Spectrum Constellation (10 MHz)						Competitor Spectrum Constellation (20 MHz)		
Baseline			Site Densification			Baseline		
Low Loaded Scenario	Medium Loaded Scenario	High Loaded Scenario	Low Loaded Scenario	Medium Loaded Scenario	High Loaded Scenario	Low Loaded Scenario	Medium Loaded Scenario	High Loaded Scenario

Number of sites

7	7	7	16, 28, 64	16, 28, 64	12, 14, 16	7	7	7

Average number of video users per cell

1	5	24	1	5	24	1	5	24

Number of test full buffer users in one of center cells

1	1	1	1	1	1	1	1	1

Objective: Determine number of sites in 3UK constellation to achieve target throughput measured in competitor

Simulation Inputs and Assumptions

NPT Prediction – Macro Network (Maidenhead HQ)

- A cluster of 7 sites is extracted from 3UK macro network around Maidenhead HQ

- Area extracted measures about 8.7 Km^2

- 7 sites of focus and the test area were selected by 3UK

- NPT tool (Atoll) is used to generate RF propagation environment

- NPT tool is used to drop randomly users.

- Users are dropped only in the 21 cells of selected 7 sites

- Video users are used to create network load

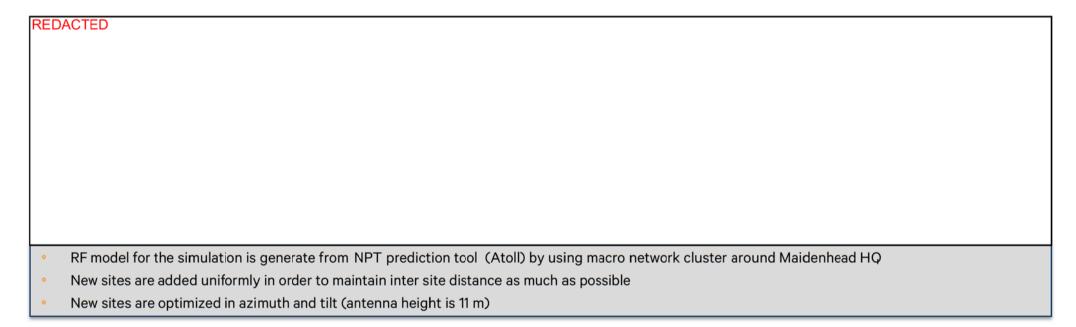- Full buffer users are used to measure target average throughput

NPT Prediction – User and Traffic Distribution

High Loaded Scenario: (drop1)
Video users (per drop) = 21 x 24

Medium Loaded Scenario: (drop1)
Video users (per drop) = 21 x 5

Low Loaded Scenario: (drop1)
Video users (per drop) = 21 x 1

Full Buffer users (per drop) = 1
All 100 drops in center cells

- Locations for video traffic users are generated randomly across the 7 sites (21 cells) macro network cluster around Maidenhead HQ
- Locations for test full buffer traffic users are generated randomly within center sites (6 cells). Full buffer users are used to measure target throughput
- 100 drops (video and full buffer users) are generated for statistical significance and used for all site densities

REDACTED

- RF model for the simulation is generated from NPT prediction tool (Atoll) by using macro network cluster around Maidenhead HQ
- New sites are added uniformly in order to maintain inter site distance as much as possible
- New sites are optimized in azimuth and tilt (antenna height is 11 m)

REDACTED

- RF model for the simulation is generate from NPT prediction tool (Atoll) by using macro network cluster around Maidenhead HQ
- New sites are added uniformly in order to maintain inter site distance as much as possible
- New sites are optimized in azimuth and tilt (antenna height is 11 m)

System Parameters (1 of 2)

	System Level parameters	3UK - Value	Competitor - Value
Channel Bandwidth	Channel frequency	1800 MHz	1800 MHz
	Deployment mode	Single carrier	Single carrier
	Bandwidth Size	10 MHz	20 MHz
	Max number of DL PRBs	50	100
Simulation Assumptions	User Distribution	Video users randomly dropped across all cells Full Buffer user randomly dropped in center cells	Video users randomly dropped across all cells Full Buffer user randomly dropped in center cells
	Number of Drops	100 drops / Scenario	100 drops / Scenario
	Simulation Time	20 s	20 s
	Traffic Types	Video and Full Buffer	Video and Full Buffer

System Parameters (2 of 2)

	System Level parameters	3UK - Value	Competitor - Value
RF Propagation	**Fast Fading Channel Model**	ITU Pedestrian B	ITU Pedestrian B
	eNodeB Antenna Height	Actual for current sites, New sites (11 m)	Actual for current sites
	eNodeB Antenna Tilt & Azimuth	Actual Azimuth, Optimized Tilt	Actual Azimuth, Optimized Tilt
	eNodeB Max Tx Power	20 W	40 W
	eNodeB Antenna Gain	17.6 dBi	17.6 dBi
Resource Management	**Scheduling Algorithm**	Proportional Fair	Proportional Fair
	DL Spatial Multiplexing	MIMO 2x2	MIMO 2x2
	Number of HARQ processes	8	8
	Max HARQ Re-transmissions	3	3
	Number of control symbols	3 OFDM symbols	3 OFDM symbols
	CQI feedback	Wideband CQI	Wideband CQI

Video and Full Buffer Traffic Models

Video Application – Definition

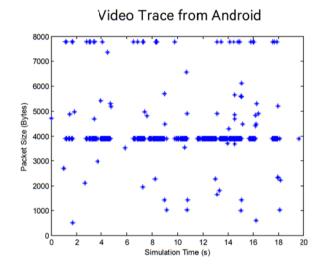Video application is a sequence of video packets separated by inter arrival time.

Video application is captured by using an Android video traces as illustrated in the picture

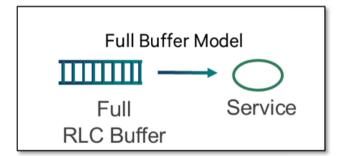Video application is not running on top of TCP protocol.

Full Buffer – Definition

FB traffic is originated by considering RLC buffer always full of bits.

FB application is not running on top of TCP protocol but it emulates UDP traffic

Video Trace from Android

Video parameters	Value
Average Packet size	4 KB
Packet inter arrival time	30 ms
Ave video Thp	1 Mbps

Full Buffer Model

Full RLC Buffer → Service

Simulation Results – Baseline Performance
3UK vs. Competitor Spectrum Constellations

Low Loaded Scenario – Baseline Summary Results

DL - Output Metrics* *Metrics are calculated in center cells (6) where test Full Buffer user is dropped	3UK				Competitor			
	Full Buffer (Mean)	Full Buffer (Median)	Video (Mean)	Video (Median)	Full Buffer (Mean)	Full Buffer (Median)	Video (Mean)	Video (Median)
UEs per Cell (#)	■	■	■	■	■	■	■	■
UE Geometry (dB)	■	■	■	■	■	■	■	■
UE SINR (dB)	■	■	■	■	■	■	■	■
UE MCS (#)	■	■	■	■	■	■	■	■
UE PRB Size (#)	■	■	■	■	■	■	■	■
UE Sched. Time (%)	■	■	■	■	■	■	■	■
UE Rank Indicator(#)	■	■	■	■	■	■	■	■
UE Thp (Mbps)	■	■	■	■	■	■	■	■
UE Sched. Thp (Mbps)	■	■	■	■	■	■	■	■

Observation
- ■■■■■■■■■■■■■■■■
- ■■■■■■■■■■■■
- ■■■■■■■■■■■■■
- ■■■■■■■

Conclusion
- ■■■■■■■■■■■■■■
- ■■■■■■■■■■■■

Medium Loaded Scenario – Baseline Summary Results

DL - Output Metrics* *Metrics are calculated in center cells (6) where test Full Buffer user is dropped	3UK				Competitor			
	Full Buffer (Mean)	Full Buffer (Median)	Video (Mean)	Video (Median)	Full Buffer (Mean)	Full Buffer (Median)	Video (Mean)	Video (Median)
UEs per Cell (#)	█	█	▪	▪	█	█	▪	▪
UE Geometry (dB)	█	█	█	█	█	█	█	█
UE SINR (dB)	█	█	█	█	█	█	█	█
UE MCS (#)	█	█	█	█	█	█	█	█
UE PRB Size (#)	█	█	█	█	█	█	█	█
UE Sched. Time (%)	█	█	█	█	█	█	█	█
UE Rank Indicator(#)	█	█	█	█	█	█	█	█
UE Thp (Mbps)	█	█	█	█	█	█	█	█
UE Sched. Thp (Mbps)	█	█	█	█	█	█	█	█

Observation
- █████████████
- ████████████
- ██████████████
- ██████████████
- ████████

Conclusion
- █████████████
- ███████████

High Loaded Scenario – Baseline Summary Results

DL - Output Metrics* *Metrics are calculated in center cells (6) where test Full Buffer user is dropped	3UK				Competitor			
	Full Buffer (Mean)	Full Buffer (Median)	Video (Mean)	Video (Median)	Full Buffer (Mean)	Full Buffer (Median)	Video (Mean)	Video (Median)
UEs per Cell (#)	██	██	██	██	██	██	██	██
UE Geometry (dB)	██	██	██	██	██	██	██	██
UE SINR (dB)	██	██	██	██	██	██	██	██
UE MCS (#)	██	██	██	██	██	██	██	██
UE PRB Size (#)	██	██	██	██	██	██	██	██
UE Sched. Time (%)	██	██	██	██	██	██	██	██
UE Rank Indicator(#)	██	██	██	██	██	██	██	██
UE Thp (Mbps)	██	██	██	██	██	██	██	██
UE Sched. Thp (Mbps)	██	██	██	██	██	██	██	██

<u>Observation</u>

- ████████████████████████████████████
  ████████████████████████████

- ████████████████████████

- ████████████████████████████
  ████████████████████

<u>Conclusion</u>

- ████████████████████████████████
  ████████████████████

Simulation Results –
Site Densification in Low Loaded Scenario

Low Loaded Scenario – User Throughput CDF

REDACTED

Low Loaded Scenario – User PRBs Allocation CDF

REDACTED

Low Loaded Scenario – User Scheduled Throughput CDF

REDACTED
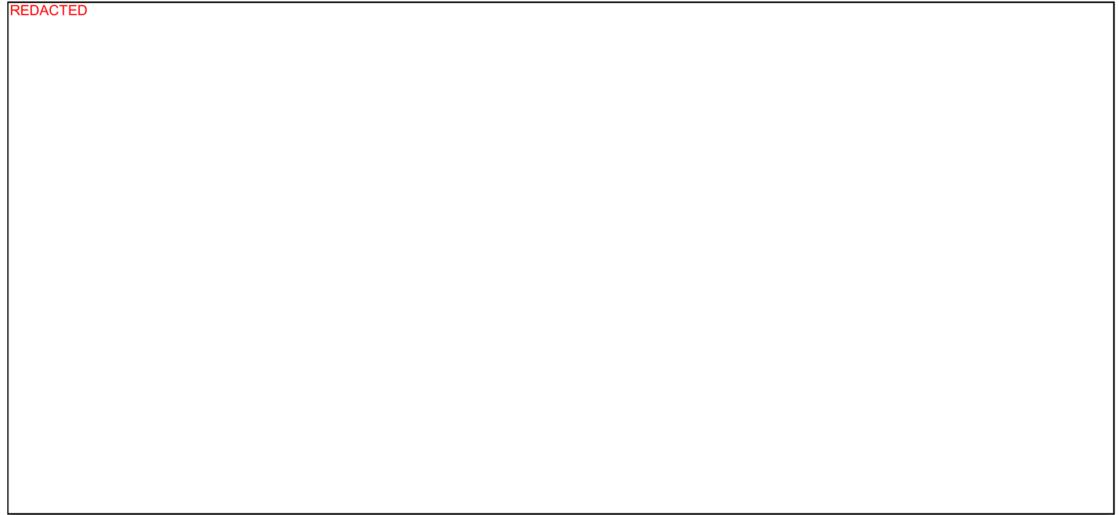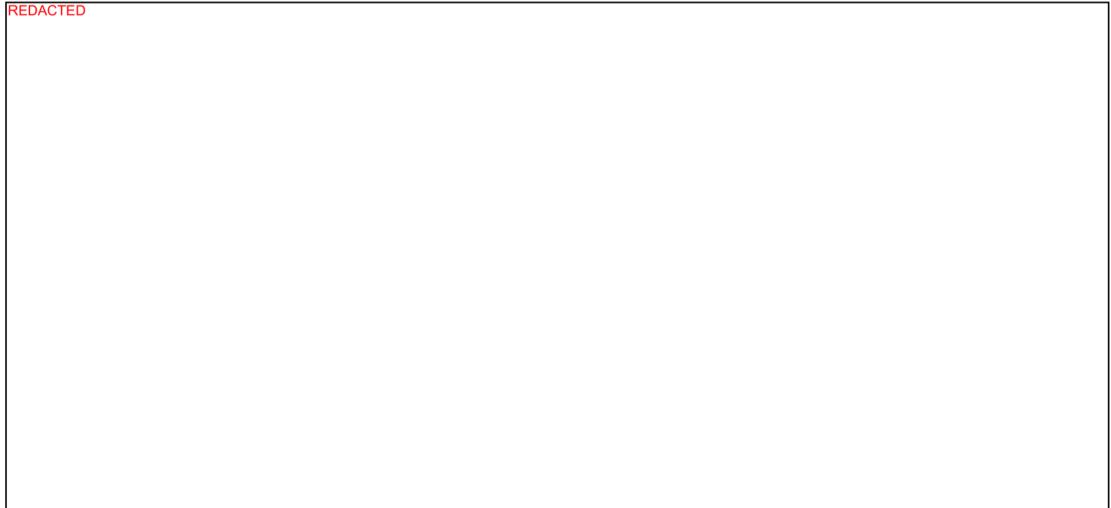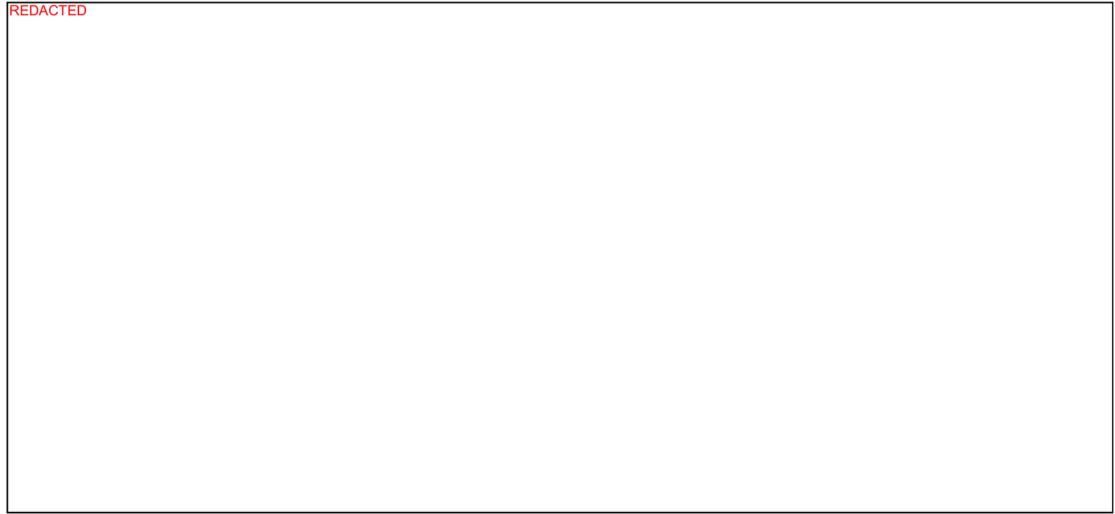
Low Loaded Scenario – User Scheduled Time CDF

REDACTED

Low Loaded Scenario – User Geometry CDF

REDACTED

Low Loaded Scenario – User SINR CDF

REDACTED

Low Loaded Scenario – User Rank CDF

REDACTED

Low Loaded Scenario – User MCS CDF

REDACTED

Simulation Results –
Site Densification in Medium Loaded Scenario

Medium Loaded Scenario – User Throughput CDF

REDACTED

Medium Loaded Scenario – User PRBs Allocation CDF

REDACTED

Medium Loaded Scenario – User Scheduled Throughput CDF

REDACTED

Medium Loaded Scenario – User Scheduled Time CDF

REDACTED

Medium Loaded Scenario – User Geometry CDF

REDACTED

Medium Loaded Scenario – User SINR CDF

REDACTED

Medium Loaded Scenario – User Rank CDF

REDACTED

Medium Loaded Scenario – User MCS CDF

REDACTED

Simulation Results –
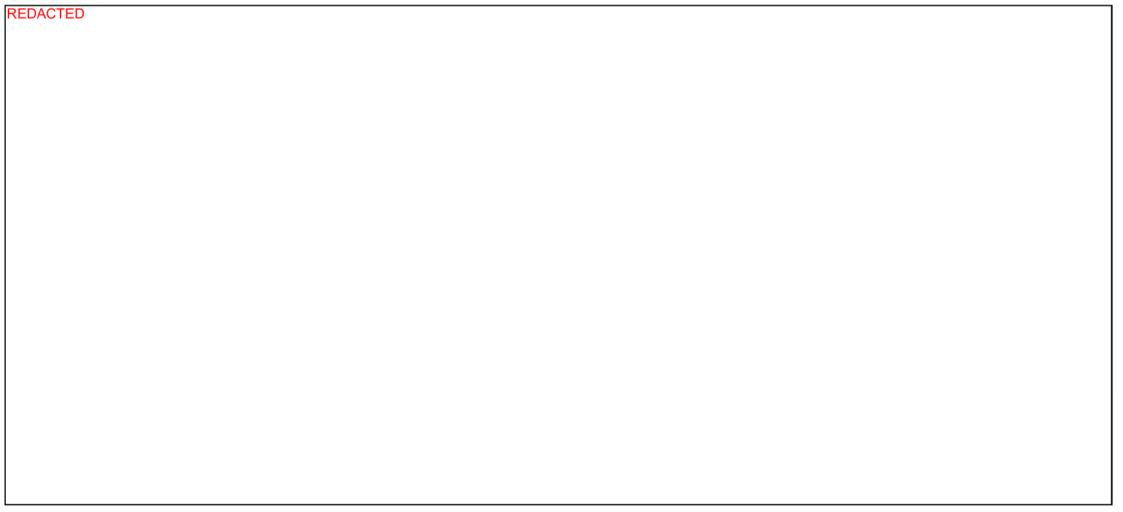# Site Densification in High Loaded Scenario

High Load Results – User Throughput CDF

REDACTED

High Load Results – PRBs Allocation CDF

REDACTED

High Loaded Scenario – User Scheduled Throughput CDF
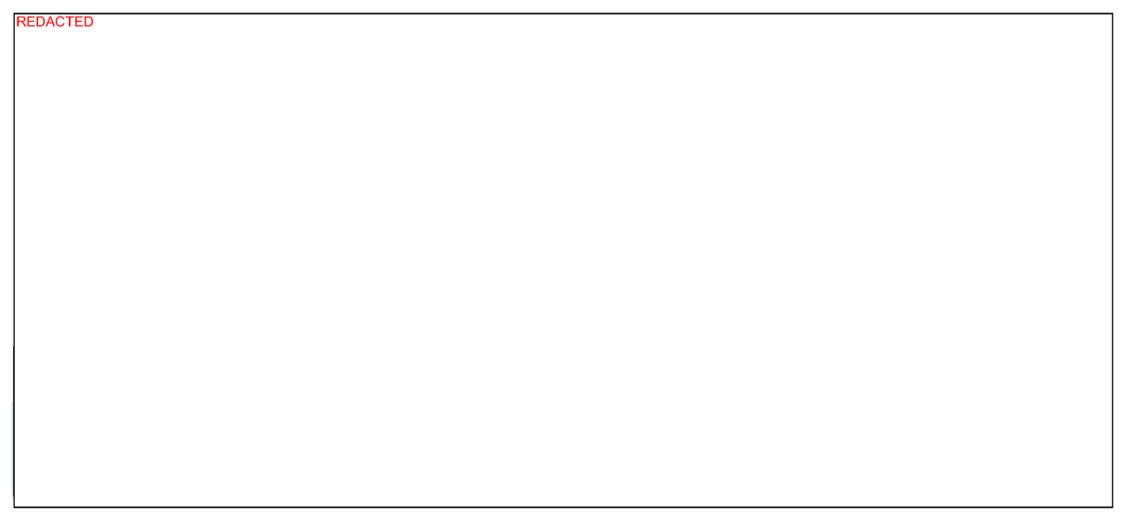
REDACTED

High Loaded Scenario – User Scheduled Time CDF

REDACTED

High Loaded Scenario – User Geometry CDF

REDACTED

High Loaded Scenario – User SINR CDF

REDACTED

High Loaded Scenario – User Rank CDF

REDACTED

High Loaded Scenario – User MCS CDF

REDACTED

Conclusions

Conclusions

Thank You