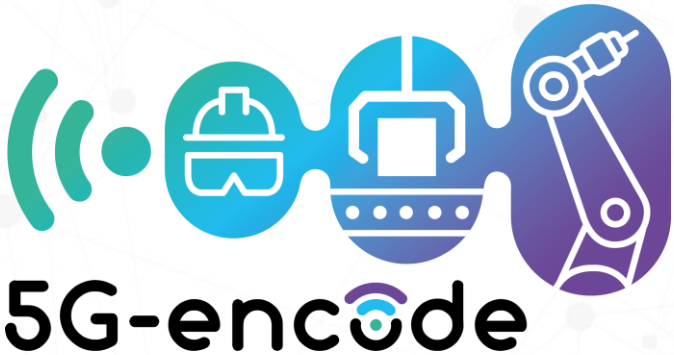

Phase 1 Network

D2.2.1: Public Case Study

INTRODUCTION

This document describes the 5G-ENCODE Project Phase 1 Network installed at the National Composites Centre (NCC) in Bristol.

About 5G-ENCODE

The 5G-ENCODE Project is a £9Million collaborative project aiming to develop clear business cases and value propositions for 5G applications in the manufacturing industry. The project is partially funded by the Department for Digital, Culture, Media and Sport (DCMS), of the UK government as part of their 5G Testbeds and Trials programme. The project is one of the UK Government's biggest investments in 5G manufacturing to date.

The key objective of the 5G-ENCODE project is to demonstrate the value of 5G on industrial use cases within the composites manufacturing industry. It will also validate the premise that using private 5G networks in conjunction with new business models can deliver better efficiency, productivity, and a range of new services and opportunities that would help the UK lead the development of advanced manufacturing applications.

The project will play a key role in ensuring that the UK industry make the most of the 5G technology and ultimately remains a global leader in the development of complex composites structures using robust digital engineering capabilities.

The project will showcase how 5G features such as neutral hosting and network slicing can be applied to transform a private 5G network into a dynamically reconfigurable network able to support a wide range of applications (URLLC/eMBB/MMTC) including industrial applications of Augmented Reality/Virtual Reality (AR/VR), asset tracking of time sensitive materials and automated industrial control though IoT monitoring and big data analytics. Such a dynamic network would enable new business models and creation of bespoke virtual networks tailored to specific applications or use cases.

The state-of-the-art testbed will be deployed across multiple sites centred around the National Composites Centre (NCC) in the South West of England. In support of the West of England Combined Authority (WECA) industrial strategy, the NCC plans to keep the testbed as an open access facility for the experimentation and development of new products and services for the composites industry after the completion of the 5G-Encode project. The location and nature of NCC's business would ensure the creation of an industrial 5G ecosystem involving multiple industry sectors and SMEs.

The project consortium brings together a Tier 1 operator (Telefonica), leading industrial players (e.g. Siemens, Toshiba, Solvay), disruptive technology SMEs covering all aspects of network design, deployment and applications (Zeetta Networks, Mativision, Plataine), a world-leading 5G network research group (High Performance Networks Group in the University of Bristol) and the NCC representing the high value manufacturing industry.

For more information about 5G-Encode, visit; https://www.5g-encode.com/ or email info@5g-encode.com

PHASE 1 NETWORK

The project has been split into 2 phases:

Phase 1 will test the use cases across 4G LTE technology to baseline the performance.

Phase 2 will upgrade the network to full 5G Stand Alone (SA) capability to provide a comparison of the improvements that 5G technology solutions can offer. The results of Phase 2 if successful will validate the need for 5G for these use cases and evidence the data points in the final report.

Phase 1 of the 5G-ENCODE project involves two locations as follows:

1. NCC Building in Emersons Green, Bristol **– Primary site**
2. NCCI Building in Filton, Bristol **– Secondary satellite site**

The network consists of an indoor 4G Private Cellular Network (PCN) at both locations procured by NCC. Market expectations are that 5G will provide an opportunity for Tier 2 vendors and suppliers to break the Tier 1 vendor dominance in this sector and to this extent the programme has procured both the radio and core network elements from Tier 2 vendors – IP Access in the Radio Access Network (RAN) and Druid for the Core Network (CN). Both vendors offered cost effective solutions and with the ability to deliver within the timescales of the project. Larger vendors in some cases have no direct channels to deal with small orders of this magnitude, as well as being considerably more expensive.

A second independent and segregated 4G network has been installed by our 5G Encode Partner Toshiba, who installed their own RAN and CN equipment in order to test and develop this towards a commercial release strategy.

The following sections describe the architecture, functional specification and verified/tested performance of the phase one network

NCC BUILDING, EMERSONS GREEN

Overview

The diagram in Fig. 1 shows the floor areas that are used within the NCC facility for hosting physical assets such as switches and servers as well as the areas where radio coverage will be provided.

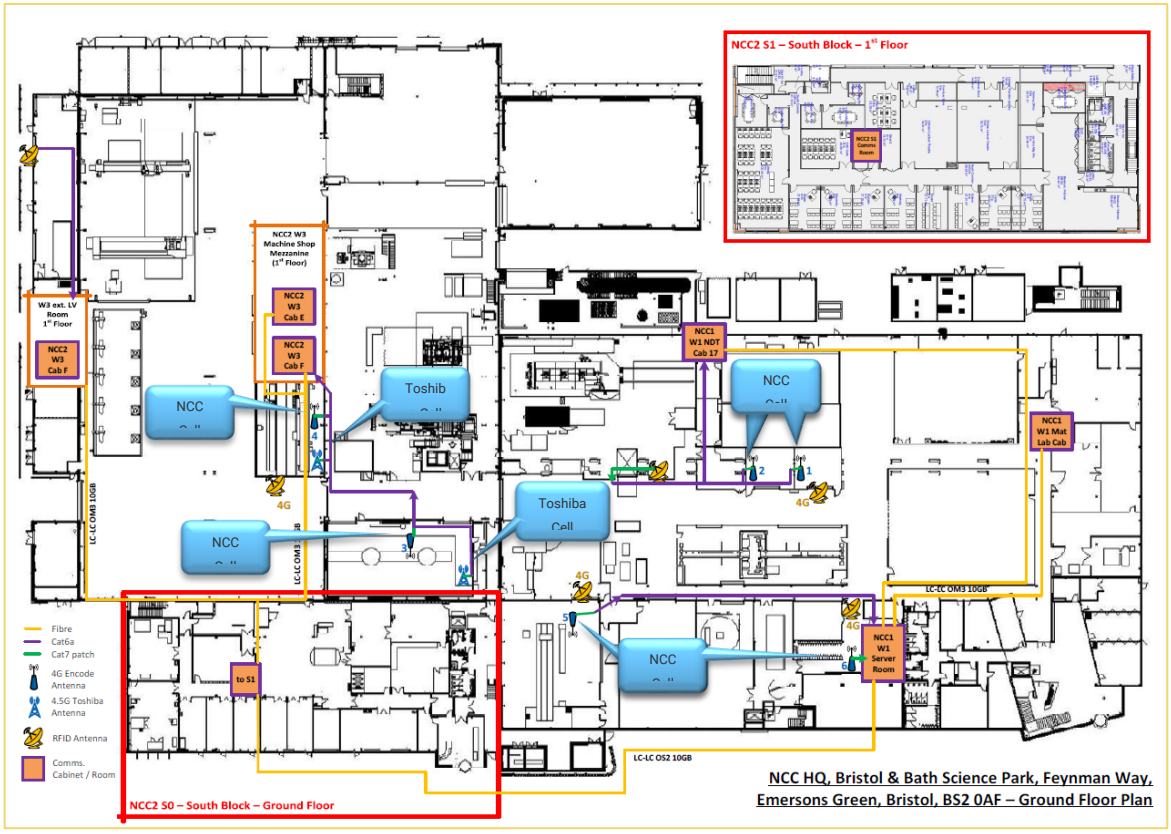

Fig. 1. NCC Building Overview

Radio Frequencies

The project has access to two operating bands for use by the project, as per the following table:

Option	License	Band	Channel Bandwidth	# Channels	Uplink Centre Frequency (MHz)	Downlink Centre Frequency (MHz)
1	Telefonica/O2 (*)	3 (FDD)	5MHz	28	1712.6	1807.6
2	Ofcom Shared Access	3 (FDD)	3.3 MHz		1783.35	1878.35

Initially the project network was configured on the shared band whilst an application was submitted for use of the Telefonica UK's band.

Network Topology

The diagram in Fig. 2 shows the logical topology of the project network in NCC.

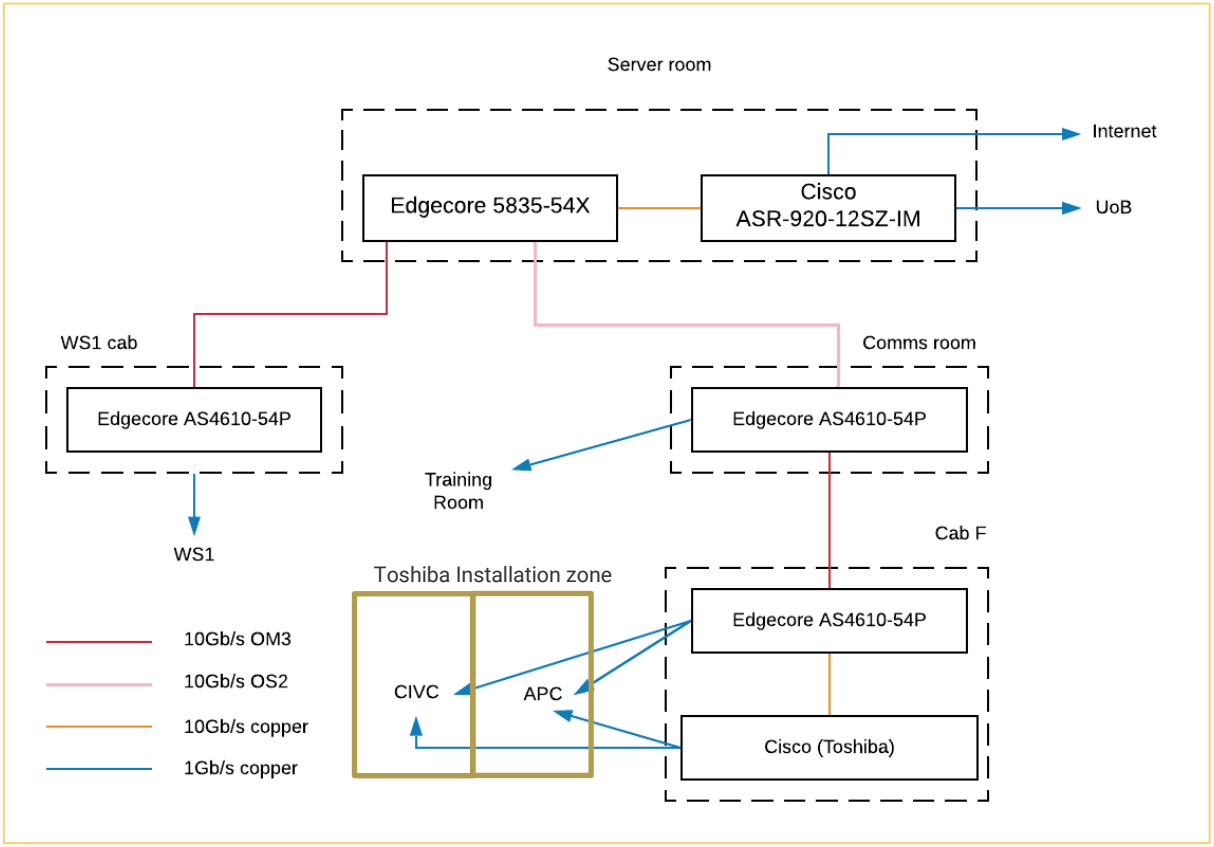

Fig. 2. NCC Network Topology

The diagram in Fig. 3 shows the physical topology across the cabinet locations.

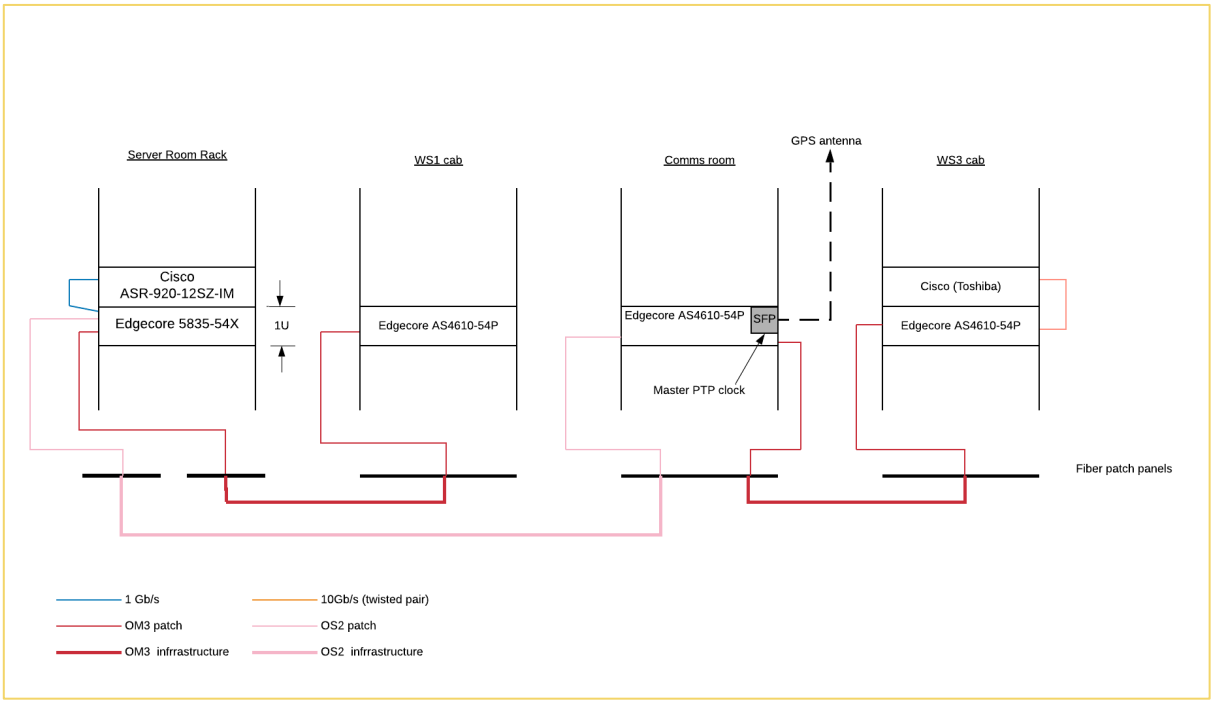

Fig. 3. NCC Physical Network

Server Room

The diagram in Fig. 4 shows the network topology of the Server Room and the different network elements installed therein.

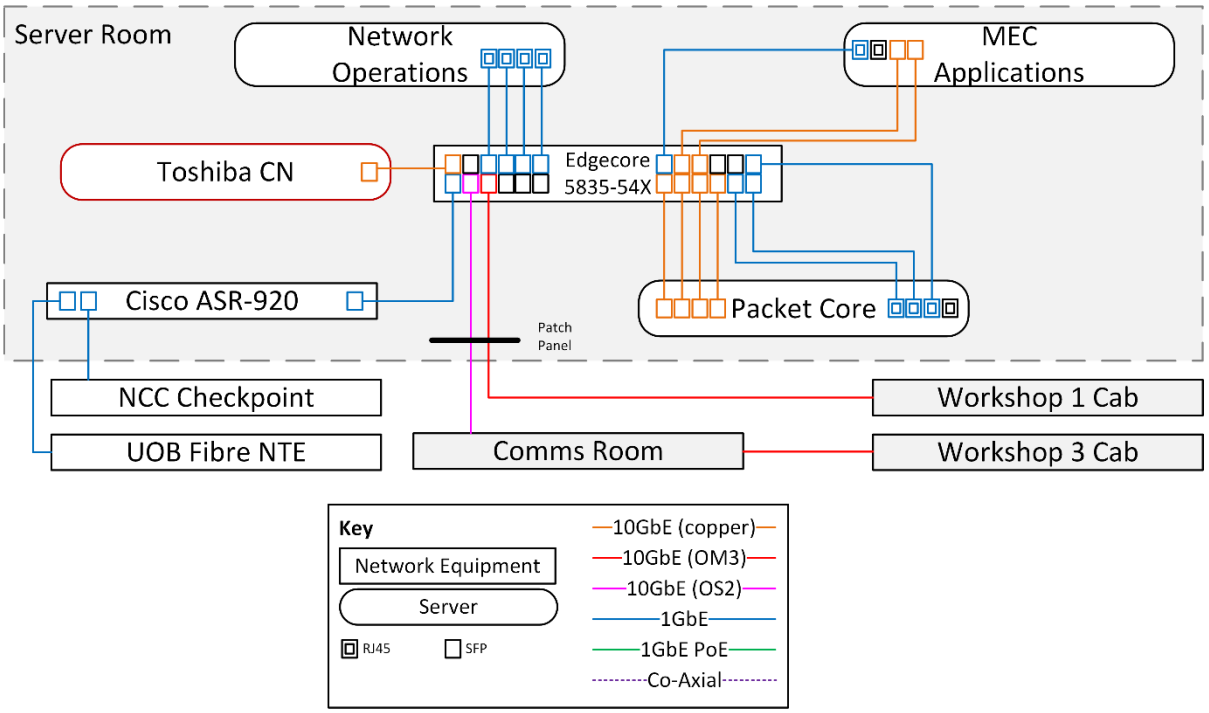

Fig. 4. NCC Server Room Network Topology

Coverage Zones

The diagram in 5 shows the areas of NCC where 4G coverage is provided, and the approximate floor area for each location. Detailed radio planning was not considered necessary for this selective coverage approach and the initial deployment will place one eNodeB radio cell into each coverage zone.

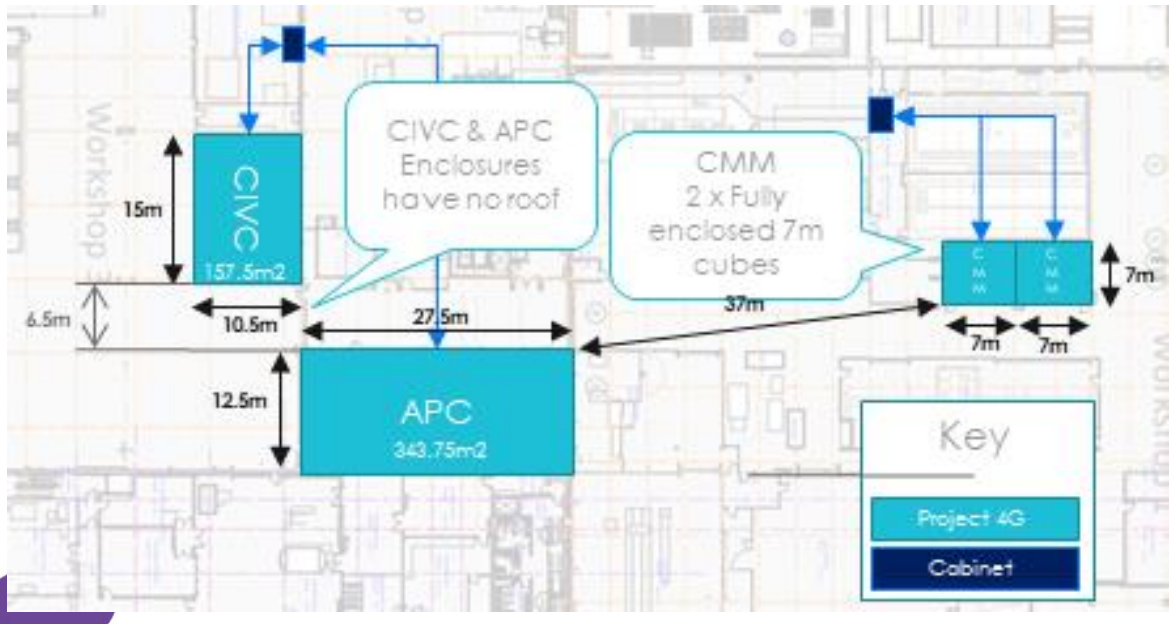

Fig. 5. NCC 4G Coverage Zones

The following table lists the coverage zones, it also shows which cabinet will provide the connectivity back to the server room. Each project 4G eNodeB is connected via the existing Cat6 and fibre cabling installed at the NCC to the server room.

Coverage Zone	Approx. Size	Approx. Area	Number of 4G eNodeB	Connectivity: From
Workshop 1 CMM-1	7m x 7m	49m2	1	Workshop 1 Cabinet
Workshop 1 CMM-2	7m x 7m	49m2	1	Workshop 1 Cabinet
Workshop 2 APC	27.5m x 12.5m	344m2	1	Comms Room
Workshop 3 CIVC	15m x 10.5m	157.5m2	1	Workshop 3 Cabinet

Management Systems

Each 4G eNodeB was provided with connectivity to:

- The Cellular NMS – this is hosted as a virtual appliance on the server stack in the server room. This provides the eNodeB with its configuration.
- The Cellular EPC – this is also hosted as a virtual appliance on the server stack in the server room.
    - Connectivity to the EPC and the Phase 2 5G SA Core is part of the Zeetta Enterprise solution, and provides the capability to orchestrate cellular services and create tailored network slices for disparate use case requirements

Due to the need to manage both the cellular and the LAN/WAN infrastructure under a 'Single Pane of Glass' view, the Zeetta Enterprise software suite has been commissioned to manage the various project assets and devices. The Zeetta Enterprise solution integrates into the CN, switching and routing network to provide service orchestration and visualisation services under a single solution, without the need to resort to individual vendor management platforms.

We believe this sort of capability will be a critical enabler to facilitate the easy adoption of 5G PCN into an enterprise IT stack, which in turn should encourage wider market adoption of such connectivity solutions.

NCCI BUILDING, FILTON

The project network deployed in the NCCI building is deployed as a Zeetta Rapide® solution. This is a portable form factor for deploying a *network in a box* that contains Zeetta Enterprise and uses a flight case with wheels that has an internal 19in rack cabinet. The solution is illustrated in Fig 6.

Fig. 6. Zeetta Rapide® Solution

4G cellular is provided to one manufacturing location in the NCCI building, which is the JLS Oven Workshop. There is no Toshiba equipment installed at the NCCi in phase 1.

NCCi Network Topology

The diagram in Fig. 7 shows the network topology for the Zeetta Rapide® installation at NCCI.

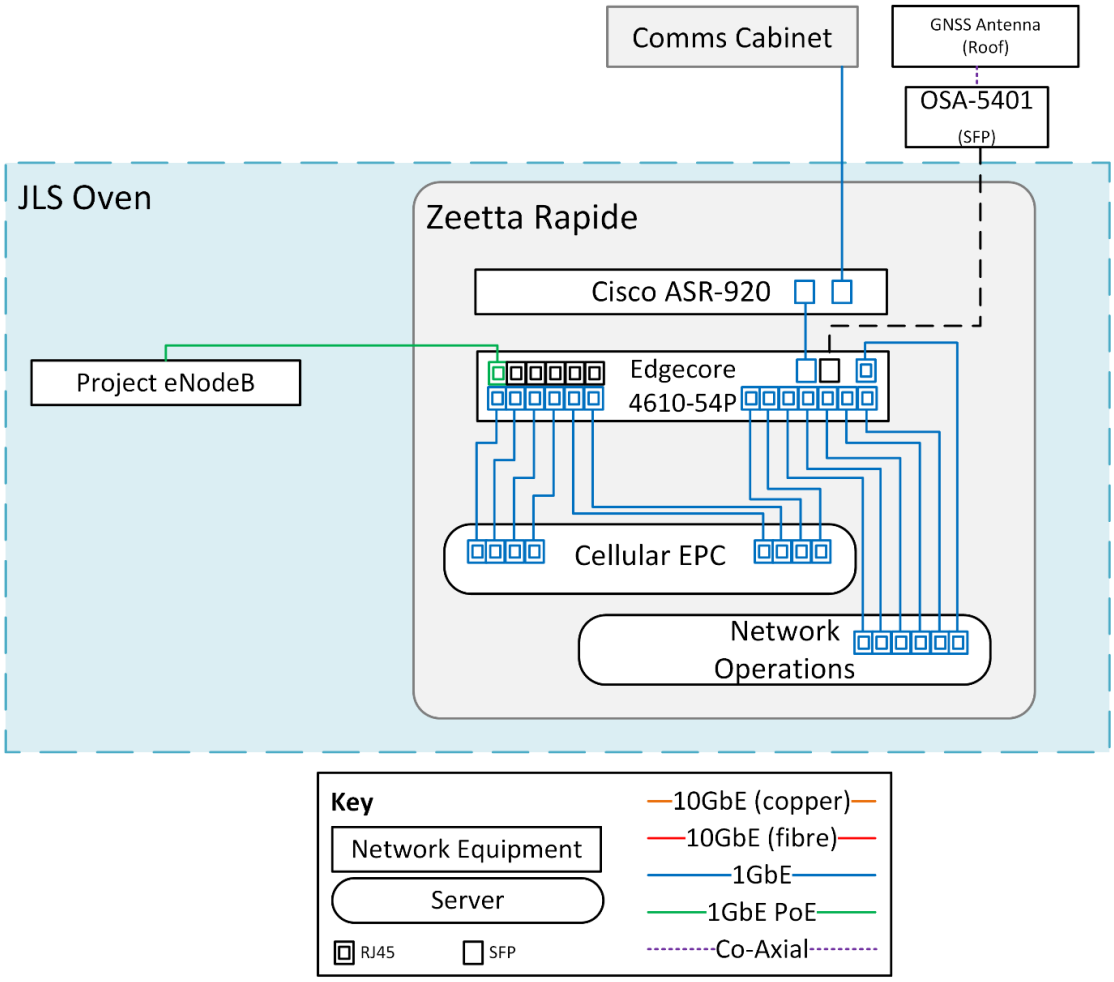

Fig. 7. NCCI Zeetta Rapide – Network Topology

Network Management

As with NCC, Zeetta Enterprise is used to manage the project devices in the network and will use Zeetta's service orchestration features to manage the connectivity across the network. The Zeetta Rapide® solution contains an embedded Cellular EPC, which forms the core network of the cellular network, and the Zeetta's service orchestration will also control the EPC. Management of the Cellular Radio Access Network is also available.

Coverage Zones

The diagram in Fig. 8 shows the area of NCCi where 4G coverage is available around the JLS oven workshop. Detailed radio planning was not considered necessary for this selective coverage approach with an initial deployment of one eNodeB radio cell into each coverage zone.

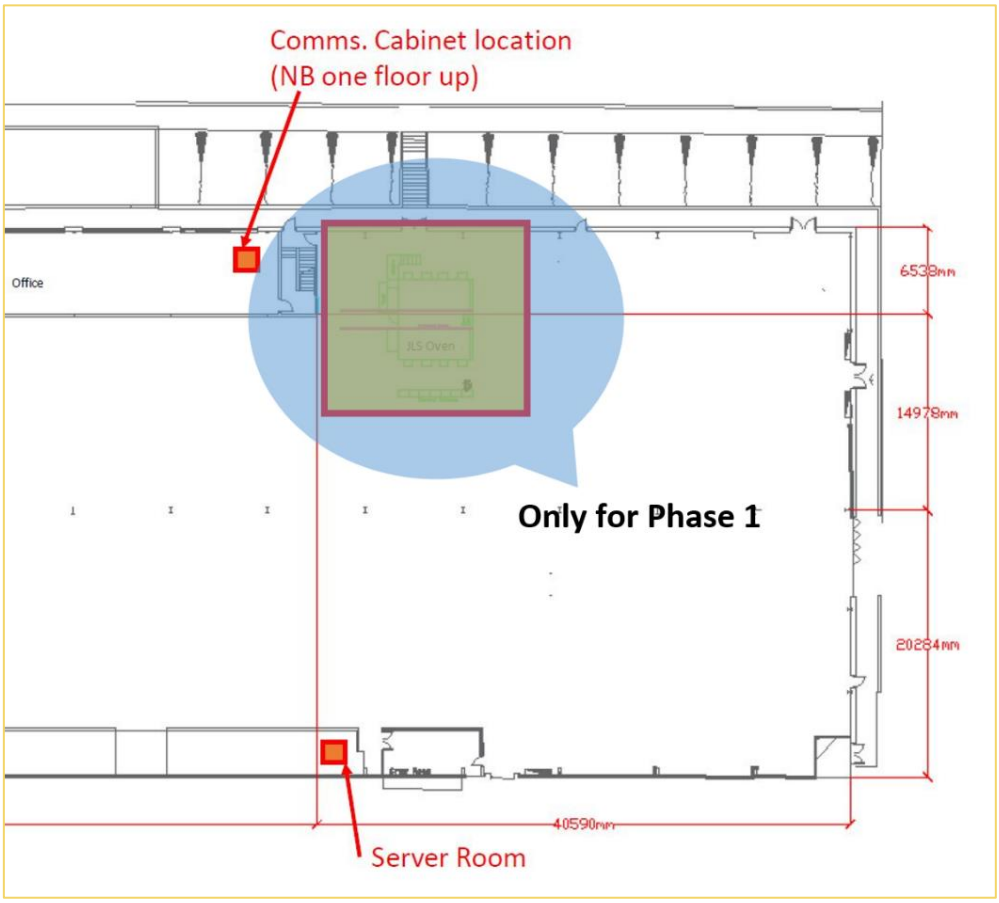

Fig. 8. NCCI 4G Coverage Zones

The following table lists the coverage zones, it also shows which cabinet is used to provide connectivity. Each project 4G eNodeB is connected back to the Rapide box through existing Cat6/Fibre cabling.

Coverage Zone	Approx. Size	Approx. Area	Number of 4G eNodeB	Connectivity: From
JLS Oven	12m x 12m	144m2	1	Zeetta Rapide®

NETWORK PERFORMANCE RESULTS

The following sections provide the verified network performance results obtained following installation and commissioning.

Overall, the system was found to be working satisfactorily and within the expected performance targets based on available network resources and spectrum.

The theoretical maximum throughput figures based on the cell capability and available bandwidth are provided below as a reference point.

- Network Bandwidth: 5MHz
- Band 3 (1800MHz)
- DL Modulation: 64-QAM & UL: 16-QAM with 2x2MIMO
- Theoretical max DL throughput: 37.5Mbps
- Theoretical max UL throughput: 12.5Mbps

CORIOLIUS CELL

	DL									UL								
	1 UE			2 Ues			3 Ues			1 UE			2 Ues			3 Ues		
AREA	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
Coriolius_1	33.6	33.6	33.6	14.2	18.6	23.0	12.3	14.8	18.7	3.8	3.8	3.8	3.3	3.8	4.2	2.7	2.9	3.1
Coriolius_2	24.6	28.5	33.9	17.4	19.1	20.9	9.7	15.6	20.7	2.0	2.2	2.3	3.4	3.8	4.1	2.7	3.0	3.2
Coriolius_3	18.2	25.5	32.3	15.2	21.5	27.7	8.1	11.7	14.3	3.4	3.6	3.8	3.9	4.0	4.1	2.9	3.0	3.2
Coriolius_4	14.2	14.6	15.4	10.4	14.7	19.0	12.4	16.8	20.9	2.6	3.3	3.8	3.0	3.3	3.5	2.6	2.8	2.9
Coriolius_4	15.0	19.7	25.5	16.1	19.2	22.3	9.4	12.4	15.9	2.7	2.8	2.9	3.5	4.3	5.2	2.7	2.8	3.1

APC CELL

	DL									UL								
	1 UE			2 Ues			3 Ues			1 UE			2 Ues			3 Ues		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
APC_1	33.5	33.6	33.8	16.0	19.4	22.8	12.0	13.4	16.2	9.7	9.9	10.2	4.7	5.1	5.5	3.0	3.0	3.0
APC_2	33.9	33.9	33.9	16.2	24.7	33.2	10.1	12.3	16.1	9.6	9.7	9.7	7.4	8.4	9.5	3.0	3.0	3.0
APC_3	33.9	34.0	34.2	17.7	23.4	29.0	14.1	15.5	17.2	9.6	9.7	9.7	4.5	5.4	6.3	3.0	3.5	4.4
APC_4	28.7	32.2	33.9	16.2	20.1	24.0	13.1	13.9	15.5	9.6	9.7	9.7	4.1	5.0	5.9	3.0	3.3	3.9

CIVC CELL

	DL									UL								
	1 UE			2 Ues			3 Ues			1 UE			2 Ues			3 Ues		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
CIVC_1	33.0	33.6	33.9	18.0	22.0	25.9	9.3	17.3	32.9	8.7	9.4	9.8	4.8	5.8	6.9	3.0	3.2	3.5
CIVC_2	33.9	33.9	33.9	16.2	16.5	16.7	8.8	14.4	19.3	9.4	9.6	9.8	4.5	4.6	4.6	3.0	3.2	3.3
outside CIVC (parking)		20.3									3.9							

PCMM CELL

	DL									UL								
	1 UE			2 Ues			3 Ues			1 UE			2 Ues			3 Ues		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
PCMM	20.2	22.9	24.7	13.1	15.2	17.4	6.8	11.6	15.1	9.3	9.5	9.7	4.3	4.6	4.8	2.9	3.1	3.3
outside PCMM	8.1	9.6	12.4	4.1	4.2	4.3	2.8	3.2	3.5	3.4	4.7	5.5	2.5	3.4	4.4	0.8	1.6	2.1

CMM CELL

	DL									UL								
	1 UE			2 Ues			3 Ues			1 UE			2 Ues			3 Ues		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
CMM	30.0	32.3	33.9	17.4	20.8	24.1	10.0	10.9	12.4	2.3	7.2	9.7	4.3	5.1	6.0	3.0	3.0	3.0

OUTSIDE SERVER ROOM CELL

	DL									UL								
	1 UE			2 Ues			3 Ues			1 UE			2 Ues			3 Ues		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
Freezer_1	33.9	33.9	34.0	16.1	23.5	31.0	6.4	13.2	17.1	6.0	7.9	9.3	4.9	5.3	5.7	2.0	2.8	3.9
Freezer_2	19.1	28.2	33.9	15.8	23.6	31.5	11.1	11.7	12.3	6.5	8.5	10.0	6.6	6.7	6.9	2.7	2.9	3.3
Freezer_3	33.9	34.0	34.1	16.2	21.3	26.4	9.5	13.5	16.0	9.4	9.8	10.3	3.5	4.6	5.6	3.0	3.3	3.5

SUMMARY

Overall, the performance of the network was in line with expectations and the DL and UL throughput results on average were as follows:

DL	UL
1 UE > 30Mbps	1 UE ~8Mbps
2 UEs ~25Mbps	2 UEs ~5-6Mbps
3UEs < 20MBps	3 UEs < 5Mbps