Mobile Networks Beyond 4G

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Abstract **- There have been four generations of wireless networks. Since its inception in the early 1980s, mobile communication has evolved with each succeeding generation emerging approximately every 10 years and introducing additional services to users. Demand for bandwidth capacity has grown with every generation. Available spectrum is being increasingly limited by competing demands, while the primary device for internet connection is steadily becoming wireless. The present mobile generation is gradually reaching its capacity limits, necessitating rigorous studies to find ways of providing greater capacity beyond the current 4G. This paper aims at proposing a 5G solution and analyzing its capacity and range.**

Keywords **- 5G, Bandwidth, Beyond 4G, HetNet, MIMO**

I. INTRODUCTION

Starting from 1981, generations of wireless networks have evolved approximately every 10 years. The present 4G network is expected to be succeeded by the next generation of wireless network around the year 2020. Recent studies forecast a mobile broadband traffic growth of up to a factor of 1000 by that year. It assumes a 10 times increase in number of subscribers and 100 times higher traffic per user per day [8]. There are more than 5 billion wireless connected mobile devices presently in use [1]. This figure is expected to be surpassed in future as subscribers base grow between 10- and 100-fold. The Ericsson white paper report, like many others believes that the transition from 5 to 50 or even 500 billion connected devices with an expanded range of requirements will pose an unprecedented challenge for the current generation of wireless networks.

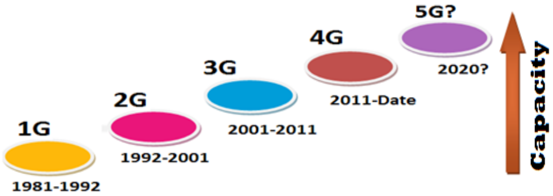

Fig. 1. Evolution of wireless networks

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II. REVIEW

Research on the next generation cellular networks is presently on-going. Specifications and standards have not been set by the standard bodies. Current investigations are taking several architectural paths for possible solutions of beyond 4G network. This paper will review a selection of what it considers the main technology solutions that would propel 5G implementation as proposed by several research papers. They are as follows:

1. Heterogeneous Networks (HetNet)
2. Spectrum
3. Massive Multiple Input Multiple Output (MIMO)
4. Interference Management

Heterogeneous Network

HetNet refers to a wireless network with an integration of multi-layer radio access technologies (RAT) such as Wi-Fi, micro wave and millimeter wave. The multi-RAT would consist of nodes with varying transmission powers and coverage sizes such as Pico, Femto, Relay Node (RN) and Remote Radio Heads (RRH) [5]. Figure 2 illustrates the structure of a HetNet.

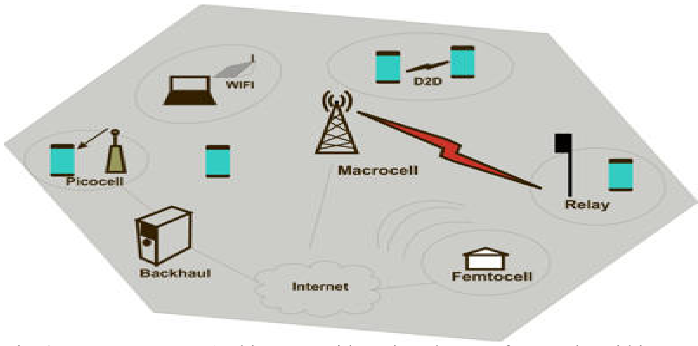

Fig. 2. Heterogeneous Architecture with various layers of networks within the macro-cell

Spectrum

Increase in wireless capacity and coverage demands have led to spectrum scarcity. Available spectrum is now been reviewed. This is leading to innovative considerations, including the possible use of new frequency bands beyond the present centimeter wave (microwave).

Extra spectrum is another way of attaining the higher data rates in a 5G system. The millimeter wave spectrum range (10GHz up to 300GHz) is being proposed for 5G small-cells. As figure 3 shows, spectrum utilization has grown with the evolution of wireless networks. Succeeding cellular generations require higher channel bandwidth.

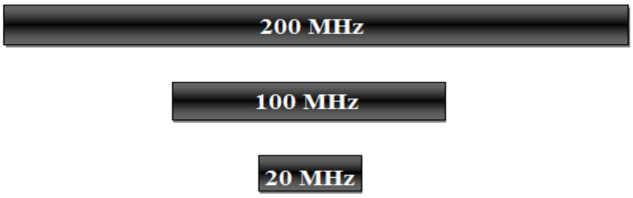

Fig. 3. Growth of channel bandwidth for 3G, 4G and 5G

Massive Multi-Input Multi-Output (MIMO)

Since ongoing investigations are increasingly pointing in the direction of network densification and use of higher frequencies in the region of millimeter wave (mm-W) as a framework for 5G networks, more research is focusing on the application of much larger (massive or enlarged) number of antennas compared to what current MIMO techniques can offer. The unique challenges associated with mm-W band such as poor link budget due to high path loss and higher dispersion effects are prompting this novel thinking. To compensate for the loss, massive MIMO antennas are estimated to be as much as 10 times the number of streams in service to all terminals. This could mean the deployment of more antenna elements in the region of tens to hundreds, which enables the achievement of considerable beam-forming gains while serving many more users in parallel [6].

Interference Management

The current 4G is still contending with co-channel interference problems despite novel management techniques such as Inter-Cell Interference Coordination (ICIC) and Coordinated Multipoint (CoMP). Because interference varies from one subframe to the next ICIC technique applies restriction on the radio resource management (RRM) block subsets that are severely affected by interference. This coordinated restriction helps to generate interference free subframes called almost blank subframe. The figure below illustrates the role of ICIC in interference mitigation.

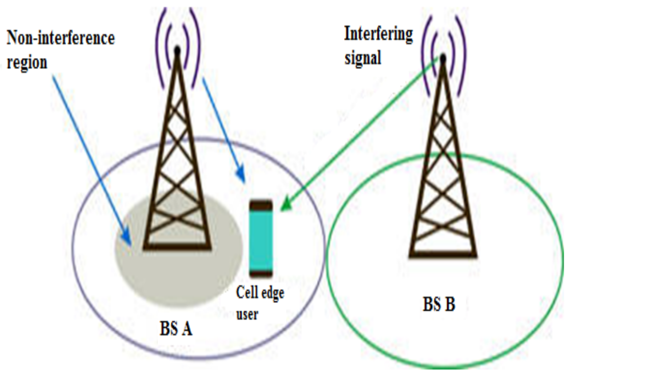

Fig. 4. Signals from an aggressor cell B interferes with the signal performance of a victim cell A. ICIC coordinates the interference between both cells.

III. SYSTEM REQUIREMENTS

System Capacity

There are several propositions arising from recent studies which suggest a broadband capacity growth reaching a factor of 1000 by the year 2020 [10]. This supposes a 10-fold rise in broadband subscribers and up to 100 times higher traffic per user per day [8]. 5G capacity therefore would require 1000 times the 4G system capacity. In order to attain this 1000 times capacity gain, spectral efficiency, BS and spectrum will contribute gains of up to 10 times current capacity. Table I shows the requirements for 5G networks as identified by this paper.

TABLE I
REQUIREMENT FOR 5G

No.	5G Network	Requirements
1	System capacity (volume)	1000 x 4G capacity
2	Peak data rate	10 Gb/s (10 x 4G rate)
3	Spectral efficiency	30 bps/Hz/cell (10 x 4G rate)
4	Energy efficiency	10 x 4G rate
5	Cell throughput	7.5 Gbps (25 x 4G rate)
6	Latency	5 x reduction in current latency

IV. PROPOSE SOLUTION

This paper has selected the same frame structure as [7] for its design solution. At the sides of the link, a small guard period (GP) is positioned at each possible switch. This is to provide alternate support for the on and off transitions. The frame consists of two main parts – the control and data parts. The first is for control and the other part for data. There is a separation of time between control and data parts. This is for a number of reasons. Power consumption is reduced by the UE as the receiver chain can go to sleep when commands are not received.

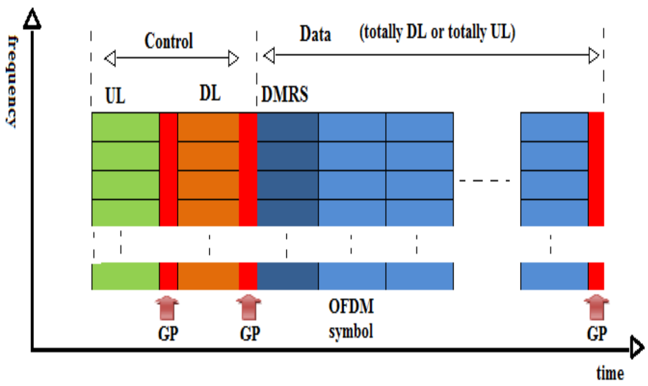

Fig. 5. Physical layer Subframe Structure

Also pipeline processing can be enhanced as user equipment can simultaneously process control and data commands at the same time. This saves cost and time hence aiding latency reduction. Some control commands are mapped to the control symbols. For instance, scheduling request (for UL), scheduling grant (for DL), modulation and coding scheme, Rank Indicator (RI) – this positions the quantity of streams to be deployed. This information can be symbolized in bits and encoded with some sort of modulation technique.

Physical Layer Parameters

TABLE II
PROPOSED SUBFRAME REQUIREMENTS FOR 5G SOLUTION

PROPOSED POSSIBLE SOLUTION FOR 5G	
Carrier bandwidth (MHz)	200
Carrier spacing (KHz)	60
Length of symbol (μs)	16.67
TTI duration (ms)	0.25
FFT size	4096
Effective subcarriers	3000
No. of Guard Periods	3
Symbols per frame	14
Duration of Cyclic Prefix (μs)	1
Duration Guard Period (μs)	0.89
Overhead	6.67
HARQ processes	4

This paper considers a modified Stanford University Interim model (SUI), as the propagation Model. Oxford city in England is used as a case study for coverage calculation. The city has the following statistics:
Population: 151, 900
Oxford Area: 45.59 km^2
Population density: 3,293 km^2 [3].

The model is formulated as follows
$PL_{SUI,\ Mod}$ [dB] (d) = α_{NLOS} x (PL_{SUI}(d) - $PL_{SUI}(d_0)$) + PL (d_0) + X_σ

Where,

α_{NLOS} = Mean slope correction factor
$PL_{SUI}(d) = PL(d_0) + 10n \log_{10}(d/d_0) + X_{fc} + X_{Rx} + X_\sigma$
$PL_{SUI}(d_0) = PL(d) + 10n \log_{10}(d_0/d) + X_{fc} + X_{Rx} + X_\sigma$
$PL(d_0) = 20 \log_{10}(4\pi d_0/\lambda)$
$n = a – b \times h_{Tx} + c/ h_{Tx}$
$X_{fc} = 6 \times \log_{10}(f_{MHz}/2000)$, fc > 2GHz
$X_{Rx} = -10.8 \times \log_{10}(h_{Rx}/2)$
λ = carrier wavelength in meters,
PL (d_0) = free space path loss in dB at a close-in reference distance d_0
d = distance between transmitter and receiver in meters
h_{Tx} = base station height
h_{Rx} = mobile station height
X_{fc} and X_{Rx} = frequency and receiver heights correction factors

X_σ = shadowing effect, $8.2 < \sigma < 10.6$ dB
C = Speed of light
f = frequency
a, b, and c = constants modeling terrain type

TABLE III
SUI TERRAIN TYPES

Terrain type[1,2,3]	Environment[1]	Terrain Parameters[2,3]
A	Hilly/Moderate to Heavy Tree Density	a = 4.6, b = 0.0075, c = 12.6
B	Flat/Moderate Tree Density	a = 4, b = 0.0065, c = 17.1
C	Flat/Light Tree Density	a = 3.6, b = 0.005, c = 20

[2][1] [9][2] [4][3]

Where,
d = 150m, h_{Rx} = 1.5m, h_{Tx} = 20m, d_0 = 50m, f = 28,000MHz, X_σ = 9.0, terrain type B, λ = C/f, f = frequency
α_{NLOS} = 0.88 (Slope correction factor selected from the model)
X_{Rx} = 1.35
X_{fc} = 6.88
n = 4.73
PL (d_0) = 95.1 dB ($20 \log_{10}(4\pi d_0/\lambda)$)
PL_{SUI}(d) = 134.93 dB (PL (d_0) + 10n $\log_{10}(d/d_0)$ + X_{fc} + X_{Rx} + X_σ)
$PL_{SUI}(d_0)$ = 99.33 dB (PL (d) + 10n $\log_{10}(d_0/d)$ + X_{fc} + X_{Rx} + X_σ)
$PL_{SUI,\ Mod}$ [dB] (d) = α_{NLOS} x (PL_{SUI}(d) - $PL_{SUI}(d_0)$) + PL (d_0) + X_σ
$PL_{SUI,\ Mod}$ [dB] (d) = 0.88 x (134.93 – 99.33) + 95.1 + 9
$PL_{SUI,\ Mod}$ [dB] (d) = 135.4 dB

Number of Cell Sites

The modified SUI propagation model gives a path loss of 135.4 dB for d= 0.15 km

Area of the Hexagonal shape for one site = $((3\sqrt{3})/2)\ d^2$

Where d = 150m (0.15km)

Area of one hexagonal cell site = $((3\sqrt{3})/2)\ (0.15)^2$ = 0.39 km^2

But Oxford area = 45.59 km^2

Hence number of cell site for coverage = 45.59/0.39 ≈ 117 cells.

V. CONCLUSION

This paper used a new path loss model, the modified Stanford University Interim Model to estimate the path loss for Oxford city in the millimeter wave frequency. It identifies 5G system requirements and proposes a design solution for the future 5G wireless networks.

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Brief description of the changes: add the second author