# Cellular phones

**Richard Harvey** 



# Mobile phones

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# What is an invention?

06

Wallace and Gromit's world of inventions, Aardman animation

20

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### Berlin Drahtlose Telephonie



"Sier Ruschte zur Beit Ede Friedrich-Behrenftraße . . . gut - bon - gemacht - tomme fofort !"

Simplicissimus magazine, 20 December 1926











![](_page_8_Picture_0.jpeg)

Frequency reuse = 7

![](_page_8_Picture_2.jpeg)

![](_page_9_Figure_0.jpeg)

![](_page_10_Picture_0.jpeg)

Analogue voice No data 1980s Digital voice 100 kbits 1990s

111

NOKIA

2\*\*\* 3\*\* 5 \*\* 6\*\*

8 tor 9 may

2G

3G

![](_page_10_Picture_4.jpeg)

Mobile data 1Mbps 2000s

![](_page_10_Picture_6.jpeg)

![](_page_10_Picture_7.jpeg)

Mobile broadband 10s of Mbps 2010s 5G

![](_page_10_Picture_10.jpeg)

Low latency Mobile broadband 100s of Mbps 2020s

## Which is the most powerful?

![](_page_11_Picture_1.jpeg)

The Cray 1 Supercomputer 1975 160 Mflops

![](_page_11_Picture_3.jpeg)

![](_page_11_Picture_4.jpeg)

**IBM Deep Blue** 1997 12 Gflops

Apple iPhone 13 2021 1500 Gflops

![](_page_11_Picture_7.jpeg)

### Buzzword bingo

Marketing Name	ITU Name	3GPP Name	RAN Name	Core Name	System Name
3G	IMT-2000	UMTS	UTRAN	UMTS Core	UMTS System
<b>4</b> G	IMT-Advanced	LTE-Advanced	E-UTRAN	Evolved Packet Core (EPC)	Evolved Packet System (EPS)
5G	IMT-2020	5G	New Radio (NR)	5G Core (5GC)	5G System (5GS)

From 5G for Absolute Beginners: Part 4 Why is 5G called 5G, Zahid Ghadialy, April 2020 <u>bit.ly/udemy5G</u>

### **Enhancement of key capabilities from IMT-Advanced to IMT-2020**

![](_page_13_Figure_1.jpeg)

### Radio altimeters

	<1GHz 30	GHz 4GHz	z 5GHz	2	24-28GHz	37-40GHz	64-71GHz	>95GHz
	600MHz (2x35MHz) 2.5/2.6GHz (B41/n41)	3.45- 3.55- 3.7- 3.55GHz 3.7GHz 4.2GH	- -Iz	5.9-7.1GHz	24.25-24.45GHz 24.75-25.25GHz 27.5-28.35GHz	37-37.6GHz 37.6-40GHz 47.2-48.2GHz	64-71GHz	>95GHz
(*)	600MHz (2x35MHz)	3.55-3.7 GHz			26.5-27.5GHz 27.5-28.35GHz	37-37.6GHz 37.6-40GHz	64-71GHz	
****	700MHz (2x30 MHz)	3.4-3.8GHz		5.9-6.4GHz	24.5-27.5GHz			
	700MHz (2x30 MHz)	3.4-3.8GHz			26GHz			
	700MHz (2x30 MHz)	3.4-3.8GHz			26GHz			
	700MHz (2x30 MHz)	3.46-3.8GHz			26GHz			
	700MHz (2x30 MHz)	3.6-3.8GHz			26.5-27.5GHz			
**	700MHz 2.5/2.6GHz (B41/n41)	3.3-3.6GHz	4.8-5GHz		24.75-27.5GHz	37-42.5GHz		
<b>*•*</b>	700/800MHz 2.3-2.39GHz	3.4- 3.42- 3.7- 3.42GHz 3.7GHz 4.0GHz		5.9-7.1GHz	25.7- 26.5- 28.9- 26.5GHz 28.9GHz 29.5GHz	37.5-38.7GHz		
		3.6-4.1GHz	4.5-4.9GHz		26.6-27GHz 27-29.5GHz	39-43.5GHz		
	700MHz	3.3-3.6GHz			24.25-27.5GHz 27.5-29.5GHz	37-43.5GHz		
		3.4-3.7GHz			24.25-27.5GHz	39GHz		

From "Making 5G a commercial reality," Qualcomm Feb 2020 https://www.qualcomm.com/media/documents/files/making-5g-nr-a-commercial-reality.pdf

### Key innovations in 5G (according to Qualcomm)

### Flexible slot-based framework

### Scalable OFDM-based air interface

![](_page_15_Picture_3.jpeg)

![](_page_15_Picture_5.jpeg)

### Scalable OFDM numerology

Low latency, URLLC, forward compatibility

### Self-contained slot structure

Address diverse services. spectrum, deployments

Advanced channel coding

![](_page_15_Picture_16.jpeg)

Multi-Edge LDPC and **CRC-Aided Polar** 

> Support large data blocks, reliable control channel

Massive MIMO

![](_page_15_Figure_20.jpeg)

Mobile mmWave

**Reciprocity-based** MU-MÍMO

Large # of antennas to increase coverage/capacity

Beamforming and beam-tracking

> For extreme capacity and throughput

From "Making 5G a commercial reality," Qualcomm Feb 2020 https://www.qualcomm.com/media/documents/files/making-5g-nr-a-commercial-reality.pdf

### 5G features - OFDM

![](_page_16_Figure_1.jpeg)

OFDM ideal transmitter and receiver diagram from <a href="https://en.wikipedia.org/wiki/Orthogonal\_frequency-division\_multiplexing">https://en.wikipedia.org/wiki/Orthogonal\_frequency-division\_multiplexing</a>

![](_page_16_Figure_3.jpeg)

## 5G features - MIMO

![](_page_17_Picture_1.jpeg)

![](_page_17_Picture_2.jpeg)

## **3G UMTS architecture - latency**

![](_page_18_Figure_1.jpeg)

![](_page_19_Picture_0.jpeg)

## Mobile telephony

Not telephony! **Massive important innovator** A tangle of standards and alphabet spaghetti Huge private investments Funded on a commercial model Another invention... but really a bundle of innovation wrapped in a protocol

![](_page_21_Picture_0.jpeg)

Integral transforms 12th April 6pm (UK time) 2022

*Operating systems* 31st May 6pm (UK time) 2022

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