

# How will wireless 5G technology handle 1 000 times more data?

Emil Björnson

*Associate Professor and Docent in Communication Systems*

**AP: Base station**

# What is wireless communication?

- Transmission of information between
  - Access point (AP)
  - User
- Digital: zeros and ones
  - Describes text, sound, images, ...

**AP: WiFi**



**User**

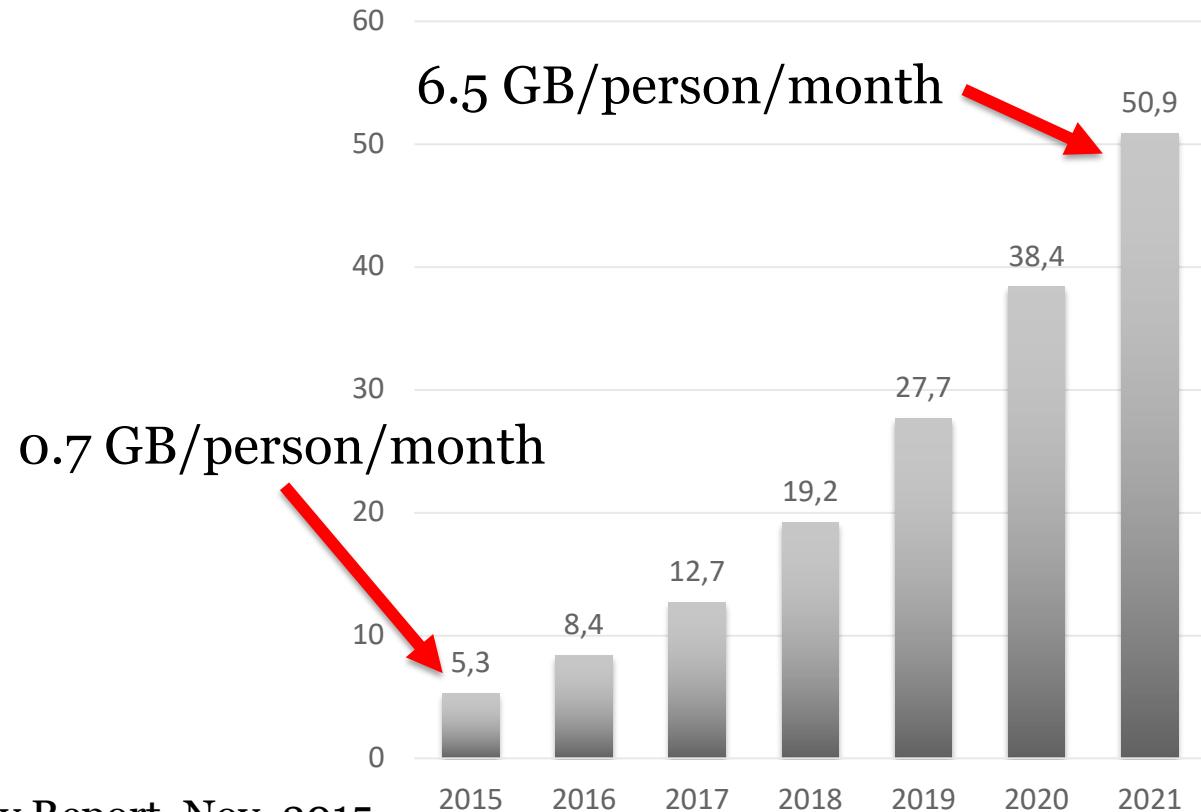


**Wireless transmission**  
(Electromagnetic signals)



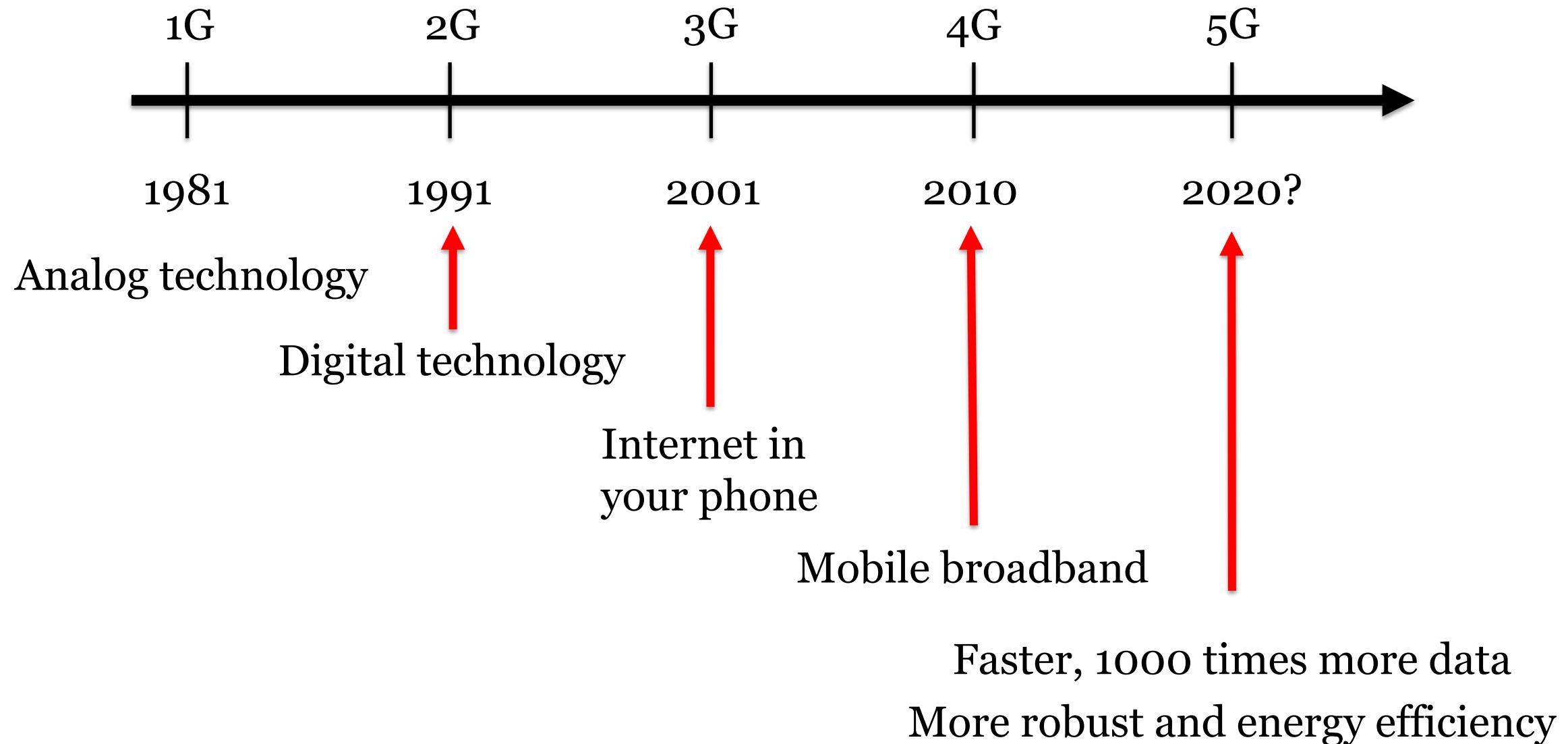
# Fast traffic growth

- Wirelessly connected society
  - Consume more GB/month
  - New applications
- Data traffic
  - 50% annual increases
  - 1000 times more until 2034
  - **Requires new technology!**

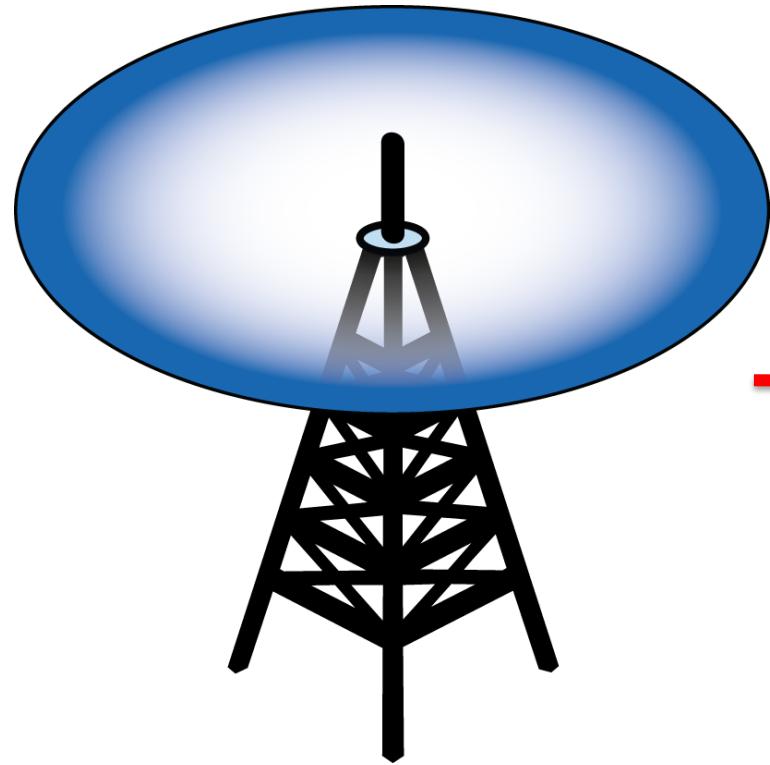


Source: Ericsson Mobility Report, Nov. 2015

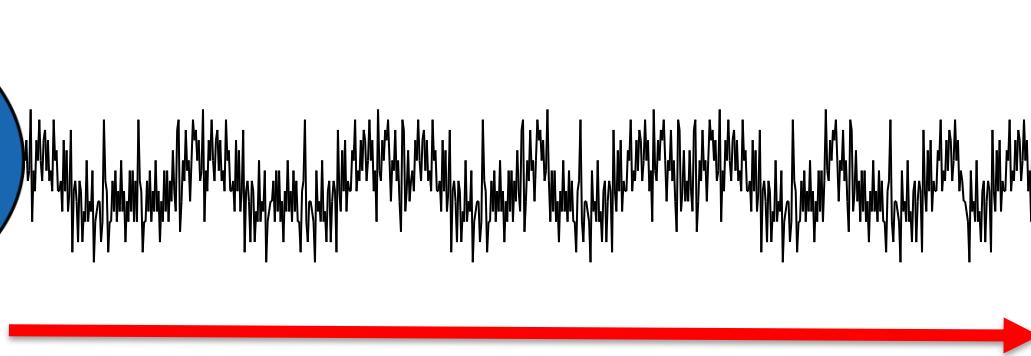
# Generations of cellular technology



# How does wireless technology work?



Antenna at access point



Electromagnetic signals



Antenna in cell phone

Flickering  
light bulb

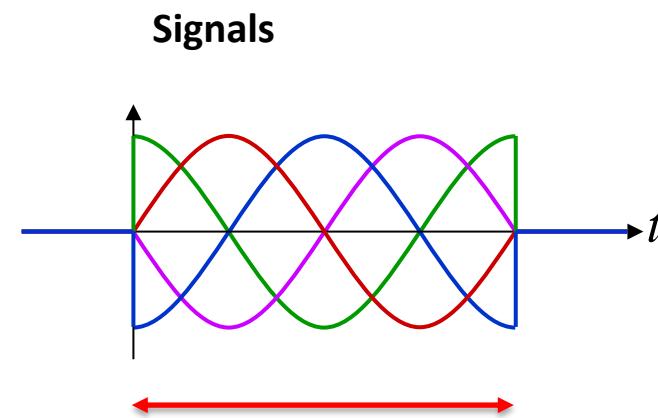
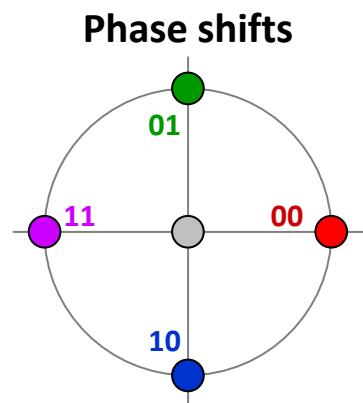
Think:

Camera

# Digital communication

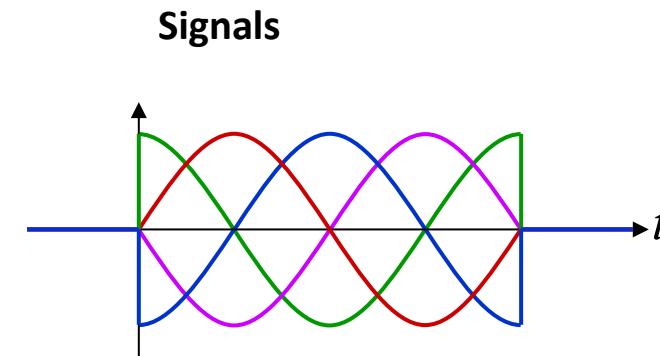
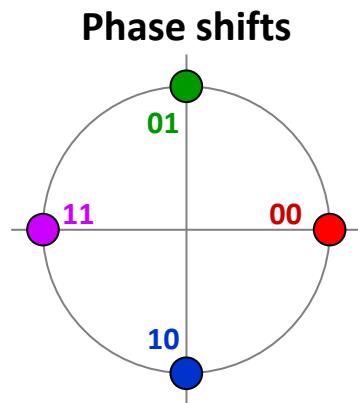
00 10 11 01 → 

- Digital bits → electromagnetic signals
  - Transmit a few zeros/ones at a time (microseconds between transmissions)
- Example: Sinus with phase shifts

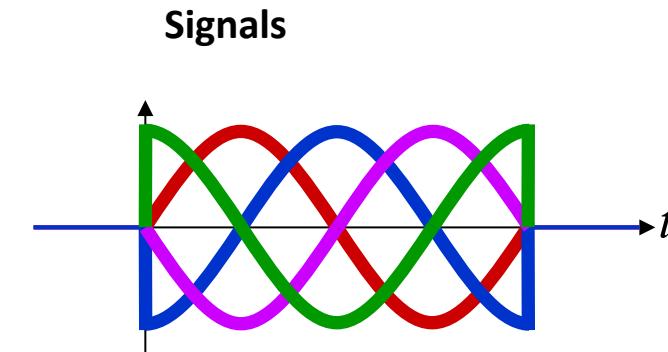
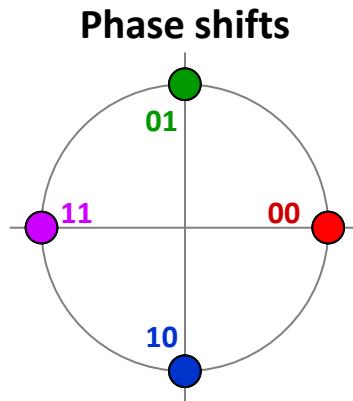


$$\text{Time} = \frac{1}{\text{Bandwidth}}$$

# Example: Digital data transmission

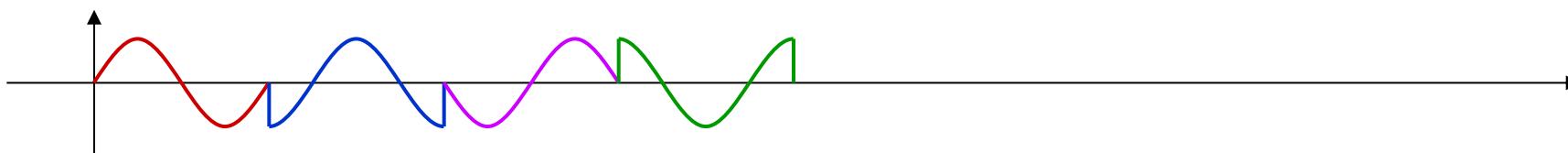


# Example: Digital data transmission

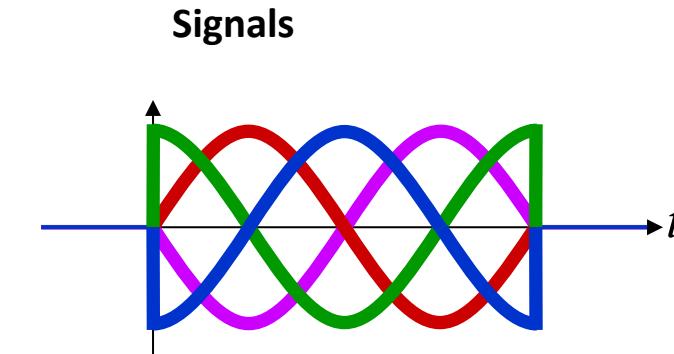
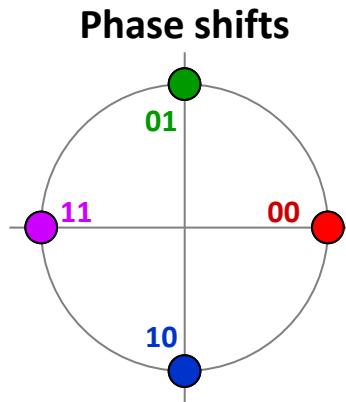


Sequence of bits to be transmitted:

**00 10 11 01 01 11 00 01 10**

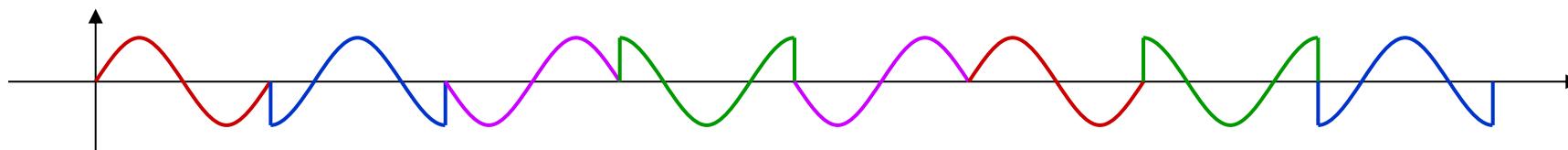


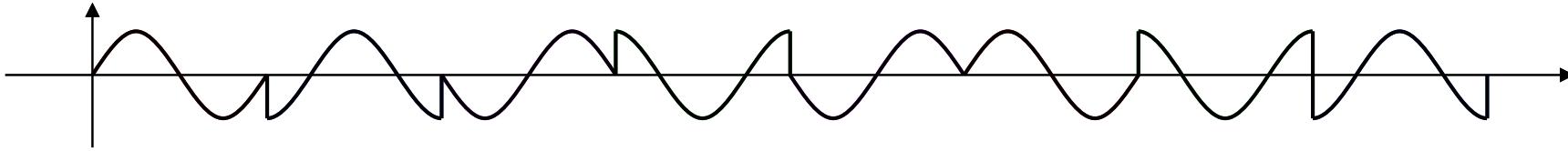
# Example: Digital data transmission



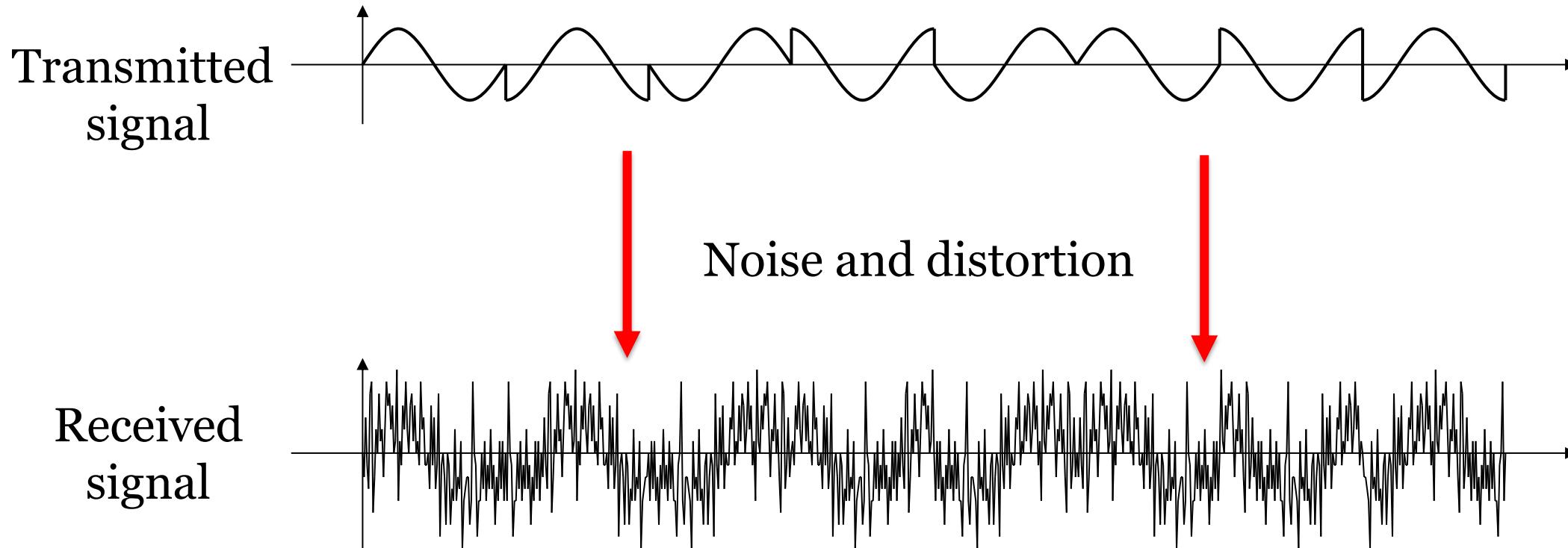
Sequence of bits to be transmitted:

00 10 11 01 11 00 01 10





# Challenge of communication



**Research problem:** Transmit as much data as possible per second

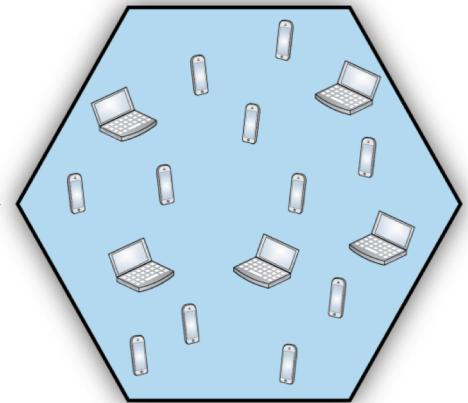
# How will 5G technology handle 1 000 times more data?

- Increasing data traffic [bit/s/km<sup>2</sup>]
  - Handle 1 000 times more traffic per area (e.g., 1 km<sup>2</sup>) →
- Formula for data traffic in cellular network:

$$\underbrace{\text{Capacity}}_{\text{bit/s per km}^2} = \underbrace{\text{Cell density}}_{\text{cells/km}^2} \cdot \underbrace{\text{Spectral efficiency}}_{\text{bit/s/Hz/cell}} \cdot \underbrace{\text{Available spectrum}}_{\text{in Hz}}$$

- Ways to achieve 1 000 times increase:

	Higher cell density	Higher spectral efficiency	More spectrum
Nokia (2011)	10x	10x	10x
SK Telecom (2012)	56x	6x	3x

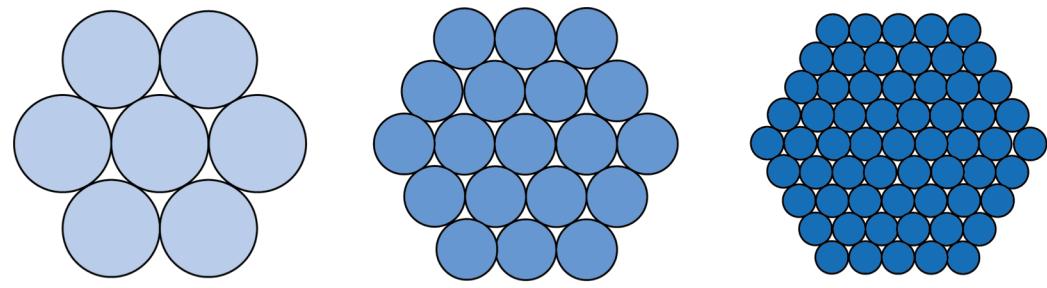
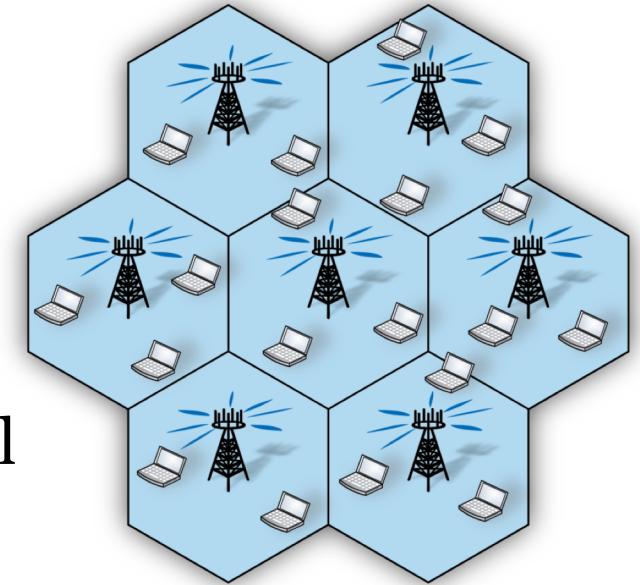


# Higher cell density

*First factor*

# Higher cell density

- Cellular networks
  - Coverage area divided into *cells*
  - One *access point* per cell – serves the users in the cell
- Denser deployment of access points
  - Shorter distance: reduce power
- Challenge: Interference
  - Higher capacity if bit/s/cell maintained



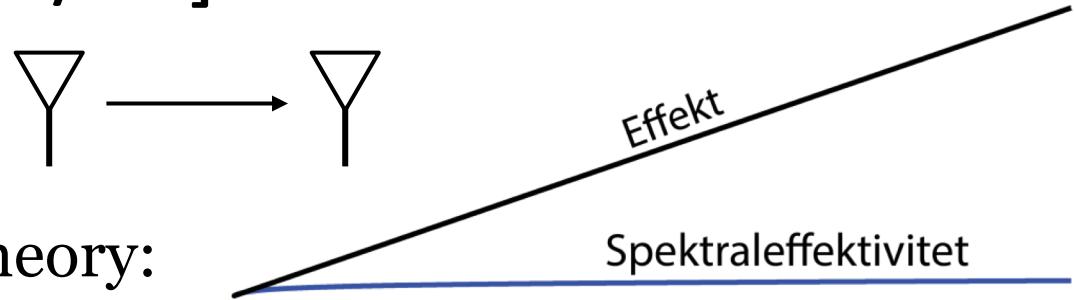
→ →

Denser and denser

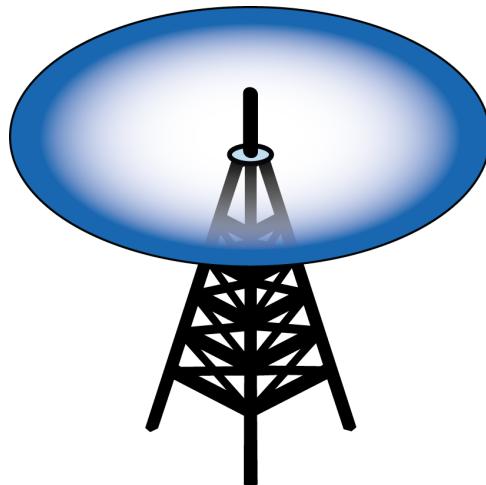
# Higher spectral efficiency

*Second factor*

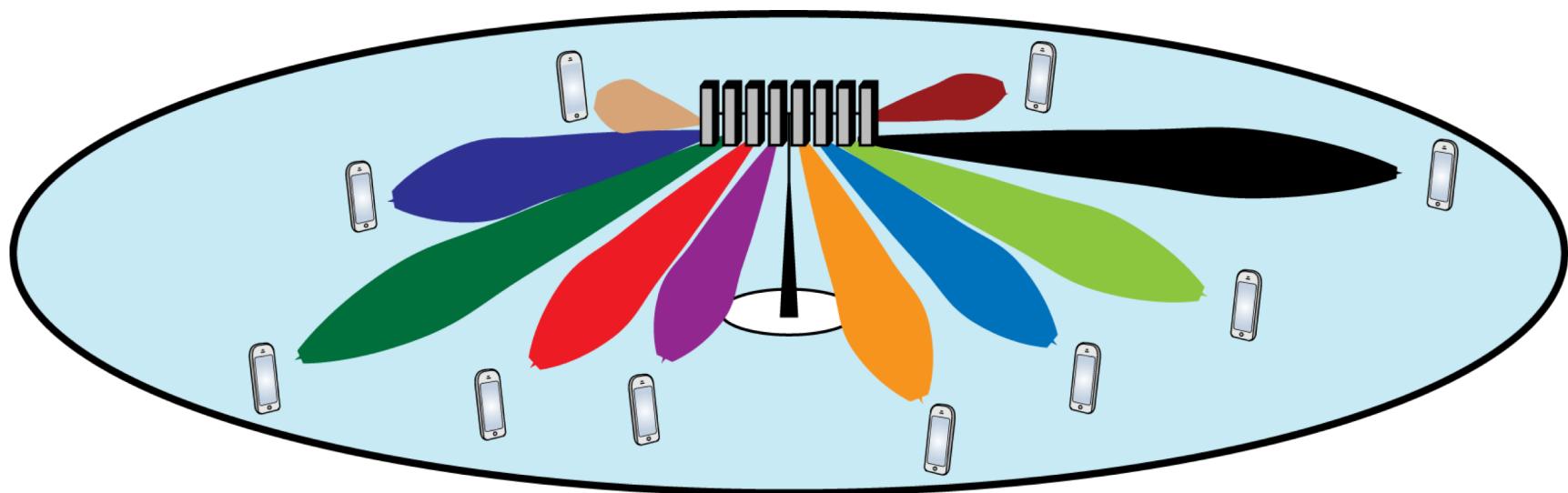
# Higher spectral efficiency [bit/s/Hz]



- Spectral efficiency from information theory:
  - Expensive to increase: Each doubling require 17 times more power!
- Solution: Many simultaneous transmissions, *directed towards the users*



1 antenna



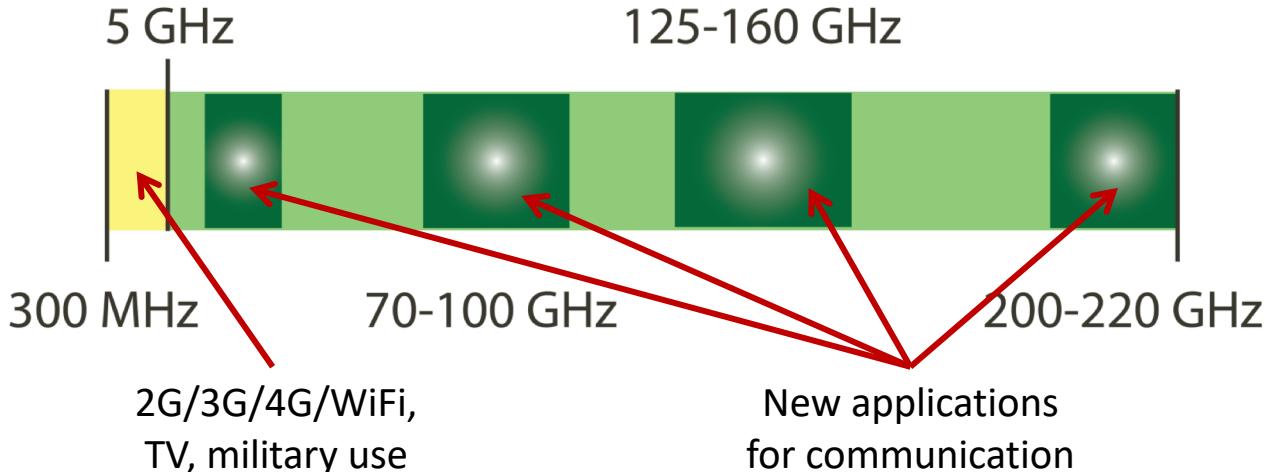
MIMO-technology: 100 antennas

# More frequency spectrum

*Third factor*

# More frequency spectrum

- More spectrum
  - Reduced time per transmission
- Are there any unused spectrum?
- Much has already been allocated
  - 580 MHz to cellular, 540 MHz to WiFi (Sweden)
  - Many GHz of unused spectrum at mm-wave frequencies (30-300 GHz)
- Challenges:
  - Signal propagation very differently
  - Design of new hardware

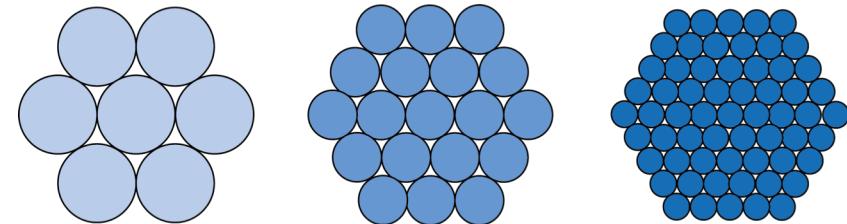


# Summary

# How will 5G technology handle 1 000 times more data?

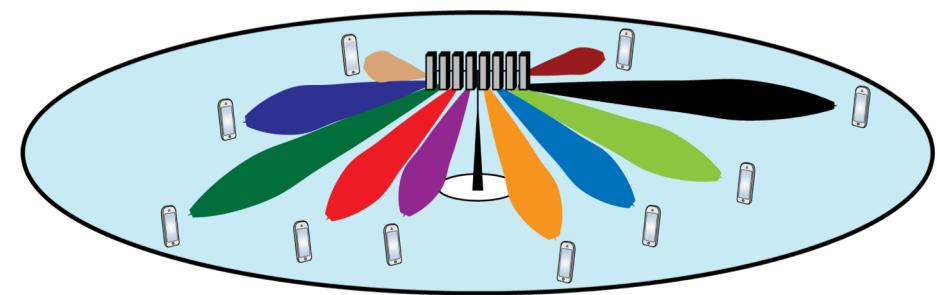
10x?

- Higher cell density
  - More access points per km<sup>2</sup>



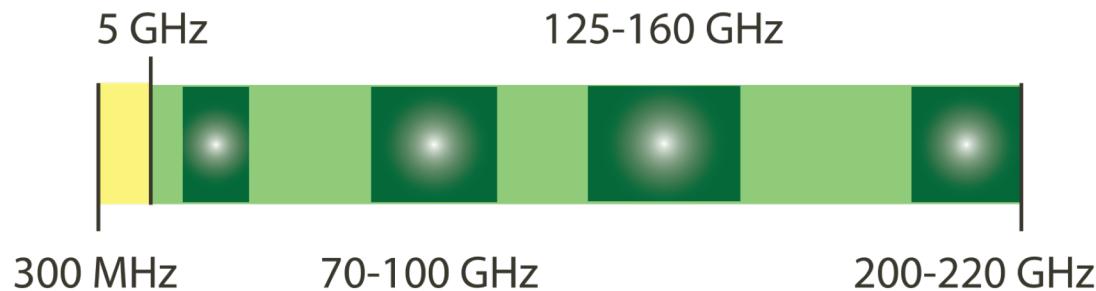
20x?

- Higher spectral efficiency
  - Direct signals towards many users



5x?

- More frequency spectrum
  - More transmission per second
  - Use much higher frequencies



=  
**1000**

# Want to know more about 5G?

- Subscribe to our YouTube channel
- Follow the Massive MIMO blog:  
**massive-mimo.net**



5G, COMMENTARY, TECHNICAL INSIGHTS

## SIX DIFFERENCES BETWEEN MU-MIMO AND MASSIVE MIMO

OCTOBER 17, 2017 • EMIL BJÖRNSON • LEAVE A COMMENT • EDIT

Multi-user MIMO (MU-MIMO) is not a new technology, but the basic concept of using multi-antenna base stations (BSs) to serve a multitude of users has been [around since the late 1980s](#).



Emil Björnson, Associate Professor in Communication Systems