

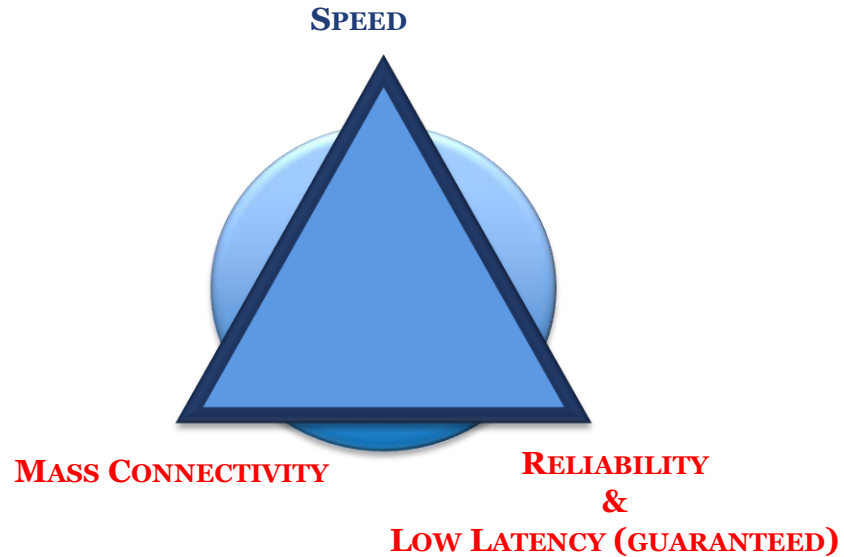
# LATENCY

## 5G WITH AN EDGE

REGIUS PROFESSOR  
RAHIM TAFAZOLLI

DIRECTOR INSTITUTE FOR COMMUNICATION SYSTEMS (ICS), 5GIC

## DIGITAL TRANSFORMATION



**LATENCY: MAIN DIFFERENTIATION BETWEEN 5G AND PREVIOUS GENERATIONS**

- **LOW LATENCIES AT ALL LAYERS, NEW PARALLEL SIGNAL PROCESSING AND COMPUTING ALGORITHMS @ THE EDGE**
- **MOST DELAYS IN PREVIOUS GENERATIONS DUE TO C-PLANE SIGNALLING**

4G INITIAL CALL SETUP TOTAL DELAY (FROM RRC IDL > CONNECTED MODE) : ~ **80 MS WITH VARIATIONS (NOT GUARANTEED)**

4G example:

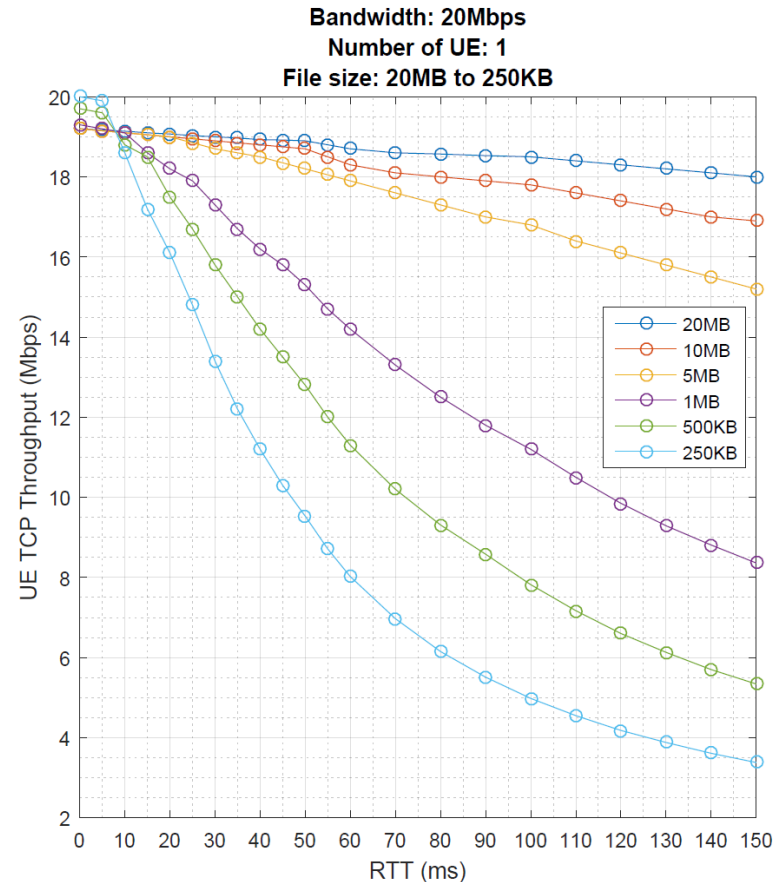


- **BANDWIDTH CAPACITY: IDEAL THROUGHPUT A UE COULD GET:**
  - MAX. DATA RATE DIVIDED BY NUMBER OF ACTIVE UES IN A CELL
- **Round-trip Time (RTT): the RTT between UE and a requested content's location can be:**
  - 15 to 40ms if available at eNB, BBU or P-GW
  - Up to hundreds of ms if not available at network edge
- **Question: How is UE's throughput affected by these different values?**

# THROUGHPUT VS. BANDWIDTH AND LATENCY (ROUND-TRIP TIME)

EXPERIMENT SCENARIO: SINGLE FILE DOWNLOAD

- THROUGHPUT IS MEASURED USING WIRESHARK IN A CLIENT-SERVER-BASED TESTBED (FIXED NETWORK)
  - RTT AND BANDWIDTH ARE MANIPULATED VIA NETWORK EMULATOR
  - SCENARIO: SINGLE FILE TRANSFER OVER TCP
- 20MBPS BANDWIDTH CAPACITY
  - LARGER DOWNLOADS ( $\geq 5\text{MB}$ ) ARE NOT AFFECTED MUCH BY LATENCY.
  - SMALLER DOWNLOADS ( $\leq 1\text{MB}$ ) ARE NEAR-LINEARLY AFFECTED BY LATENCY
  - AS A DOWNLOAD BECOMES SMALLER, IT IS AFFECTED MORE BY LATENCY (I.E., THROUGHPUT DROPS QUICKER AS LATENCY INCREASES).

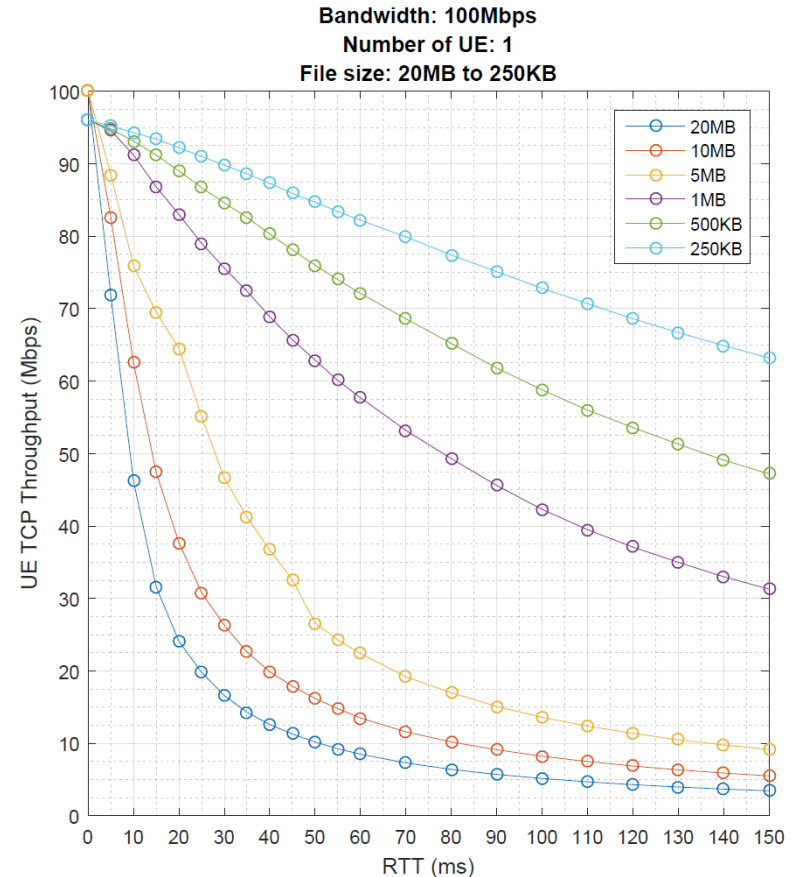


# Throughput vs. Bandwidth and Latency (Round-Trip Time)

Experiment Scenario: Single File Download

- 100Mbps BANDWIDTH CAPACITY

- DOWNLOAD THROUGHPUT IS AFFECTED MORE COMPARED WITH THE 20Mbps BANDWIDTH.
- UNDER HIGHER BANDWIDTH, IT IS EASIER FOR LATENCY TO BECOME THE BOTTLENECK.
- LARGER DOWNLOADS ( $\geq 5\text{MB}$ ) ARE NEAR-LINEARLY AFFECTED BY LATENCY.
- SMALLER DOWNLOADS ( $\leq 1\text{MB}$ ) ARE AFFECTED MORE BY LATENCY, ESPECIALLY AT 10-50ms (EXPONENTIALLY).



INSTITUTE FOR COMMUNICATION SYSTEMS

5G INNOVATION CENTRE



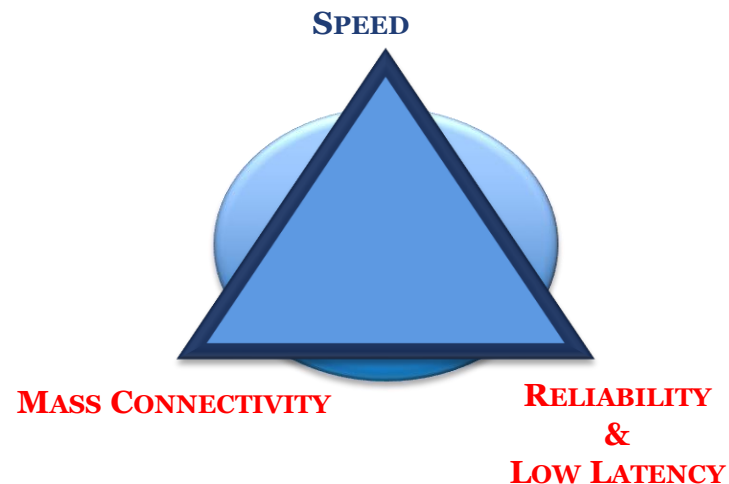
4K 360 Video Streaming  
5G vs. 4G

End-to-end latency: 100ms

Video bitrate: 200Mbps

BEYOND MOBILE BROADBAND

**ARTIFICIAL INTELLIGENCE  
&  
ULTRA RELIABLE AND LOW LATENCY  
COMMUNICATION  
&  
MASS CONNECTIVITY (IoT)**

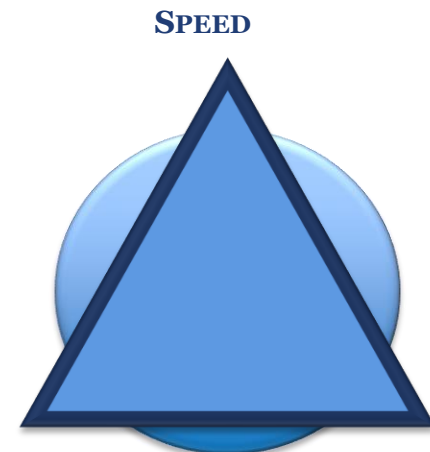




# AUTOMATION

## DIGITAL TRANSFORMATION

- **EXAMPLES:**
  - **LOGISTICS/TRANSPORT**
  - **MANUFACTURING**
  - **GAMES/ENTERTAINMENT**
  - **UTILITIES**
  - **HEALTH**



**MASS CONNECTIVITY**

**RELIABILITY  
&  
LOW LATENCY**

**LATENCY: MAIN DIFFERENTIATION BETWEEN 5G AND  
PREVIOUS GENERATIONS**



# THANK YOU

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