Performance Issues of TCP and MPEG-4 over UMTS

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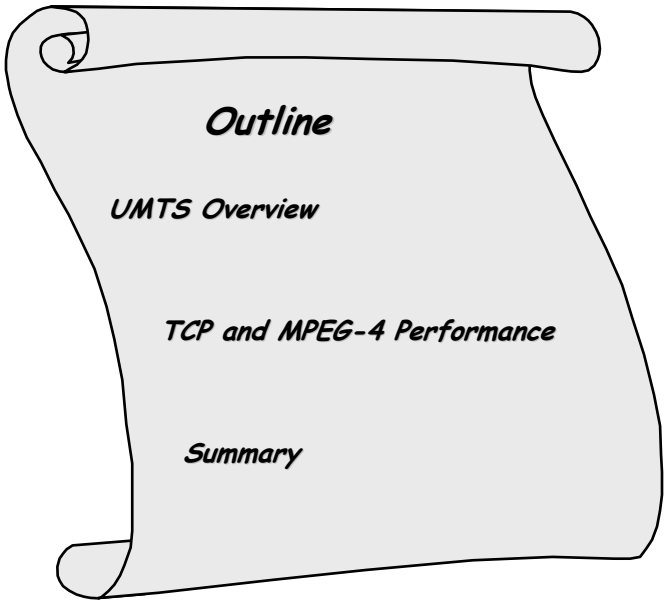
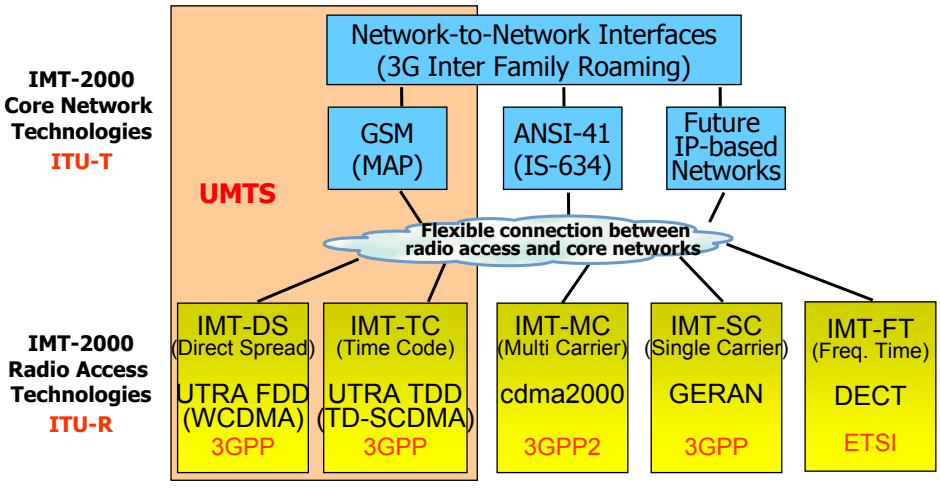


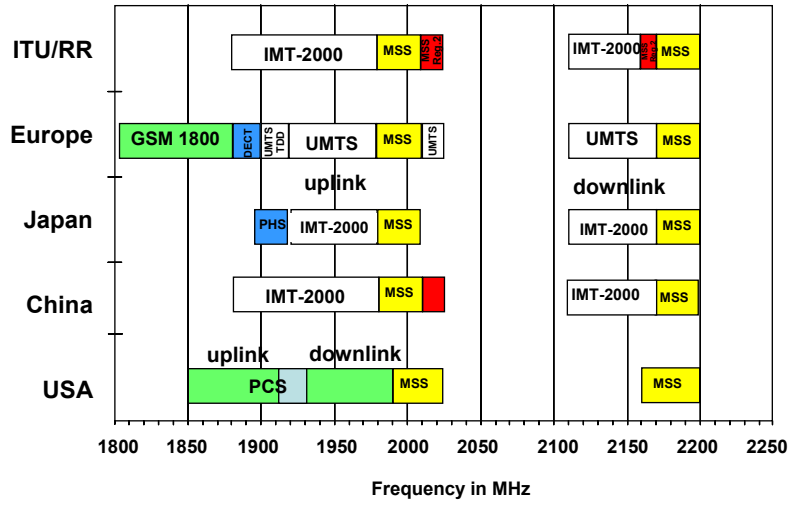
Universal Mobile Telecommunications System (UMTS)

- Radio interface is based on Wideband Code Division Multiple Access (WCDMA)
- Support of variable bit rates:
  - up to 384 kb/s in wide area coverage,
  - up to 2 Mb/s in indoor/short-range outdoor
- Support four Quality of Service traffic classes:
  - Conversational: low delay – voice
  - Streaming: low delay – video streaming
  - Interactive: moderate delay – web browsing
  - Background: no delay requirement – FTP, Email

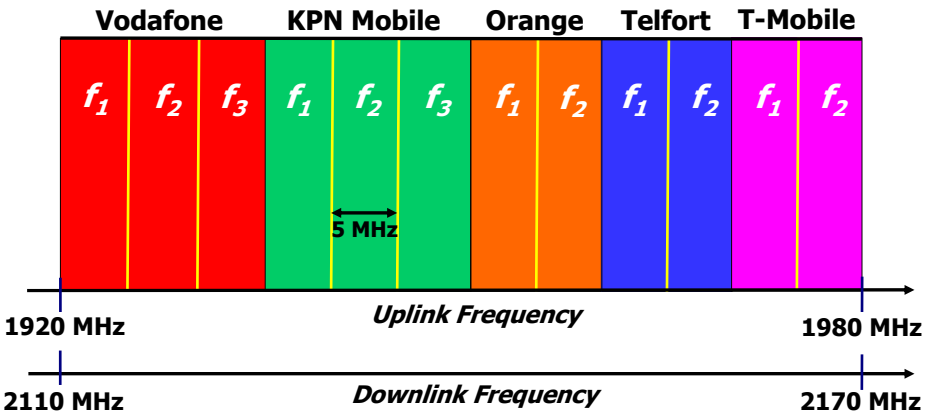
IMT-2000 Family of 3G Systems



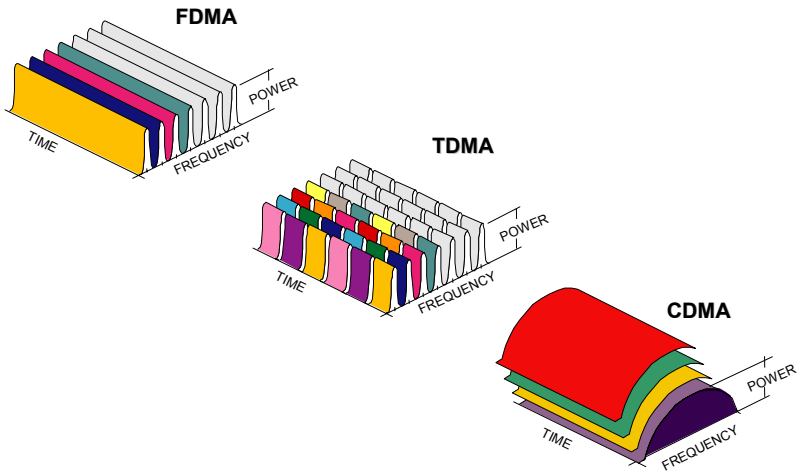
IMT-2000 Frequency Spectrum



Frequency Spectrum – The Netherlands

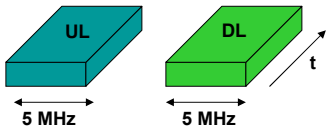


UMTS – Wideband CDMA (WCDMA)

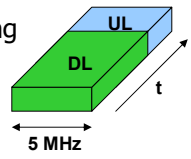


FDD ⇔ TDD

- FDD (Frequency Division Duplex)
  - separated frequency bands for Up- and Downlink
  - most suited for symmetrical services, e.g. voice, video telephony
  - paired frequency bands needed
  - used for WCDMA

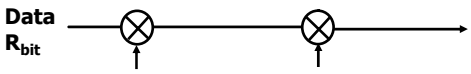


- TDD (Time Division Duplex)
  - Up- and Downlink signal within the same frequency band, but separated in time
  - also suited for asymmetrical services, e.g web browsing
  - flexible allocation in unpaired frequency band possible
  - Time synchronization needed
  - will be used for private indoor services



UMTS – WCDMA Spreading Operation

- The operation of spreading in a WCDMA system is divided into two separate parts:
  - Spreading code = Channelization code + Scrambling code



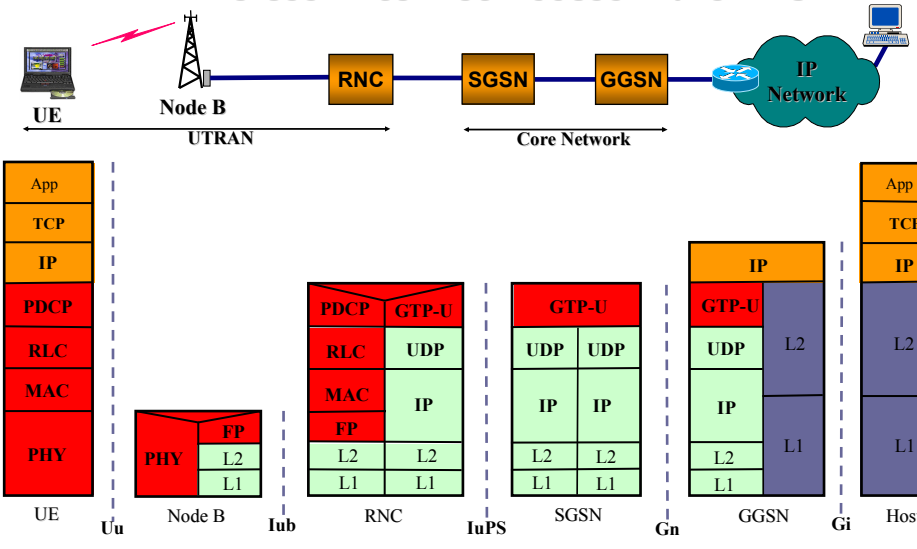
Channelization code
Chip rate
R_{chip} 3.84 Mc/s

Scrambling code
Chip rate
R_{chip} 3.84 Mc/s

Spreading factor (Processing gain)

$$G = \frac{R_{chip}}{R_{bit}}$$

Wireless Internet Access via UMTS



Packet Data Transmission over UMTS Radio Interface

- IP packets can be carried using different types of UMTS/WCDMA Transport Channels:
  - Dedicated Channel (DCH):
    - power control
    - resources allocated to a UE
    - high channel bits rates => high volume of data
  - Common Channel (CCH):
    - no power control
    - shared resources
    - low channel bit rates => low volume of data
    - Random Access Channel (RACH) – uplink
    - Forward Access Channel (FACH) – downlink

Transmission Control Protocol

- The main Transport protocol in the Internet protocol suite
- Functionality:
  - provide end-to-end reliability on top of unreliable IP network,
  - provide in-sequence packet delivery,
  - detect and prevent network congestion
- TCP uses complex mechanisms:
  - Slow start and Congestion avoidance
  - Fast retransmit and recovery

TCP Vegas vs. Reno

TCP Vegas

- Better performance than Reno
- *Proactive* network congestion algorithms
  - Slow Start – *Window (WND)* is increased for every other RTT
  - Δ = (expected – actual) × RTT_{base}

    $\Delta < \alpha$ (α =1), WND linearly increases

    $\Delta > \beta$ (β =3), WND linearly decreases

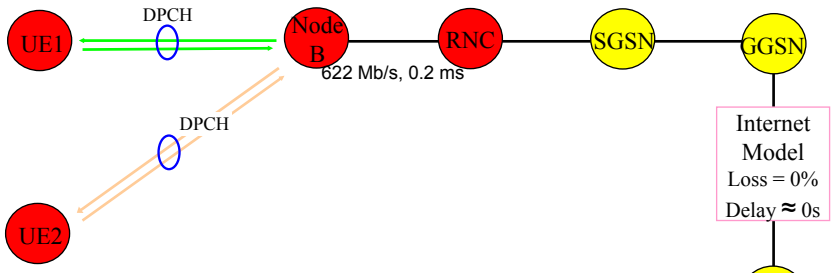
    expected = WND/RTT_{base}

    actual = WND/RTT

TCP Reno

- *Reactive* network congestion algorithms
  - Slow Start – *Window (WND)* is increased for every RTT
  - Packet losses signal congestion
    - Timeout
      - WND = 1
    - Duplicate ACKs (Fast Retransmit)
      - WND = WND/2

Simulation Model



Assumptions:

- analyze the impact of the radio interface
- UMTS Core Network and Internet:
  - loss = 0%
  - propagation delay ≈ 0s

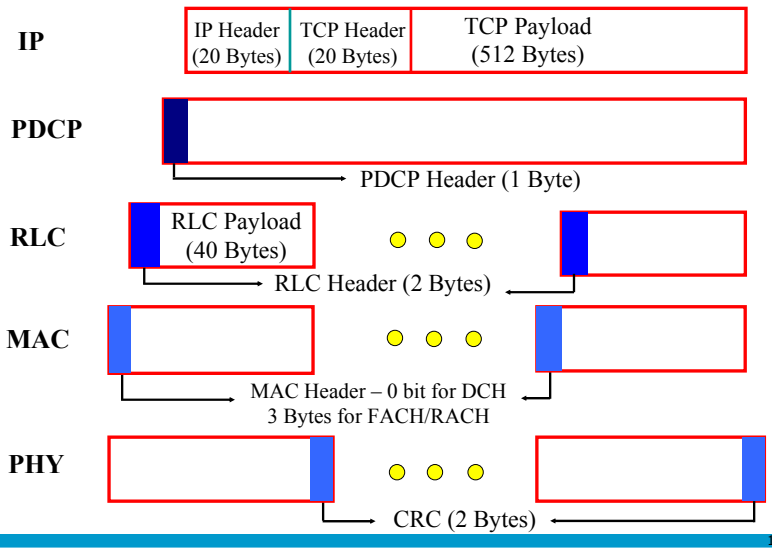
ns - UMTS Nodes

ns - traditional Nodes

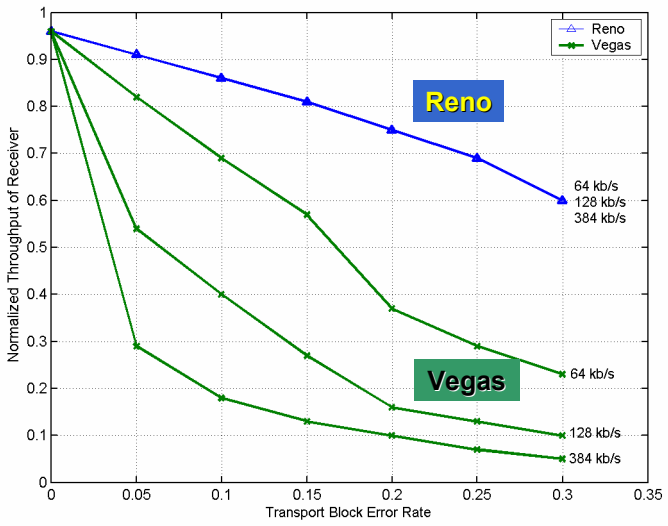
Simulation Parameters

Application	File Transfer Protocol (FTP)				
TCP	TCP Variants	Vegas and Reno			
	Window Size (Segments)	64			
	Maximum Segment Size (Bytes)	512			
	TCP Header Size (Bytes)	20			
IP	IP Header Size (Bytes)	20			
	IP Packet Loss Rate in the Internet	0%			
PDCP	TCP/IP Header compression	No			
RLC	RLC Mode	Acknowledged Mode with In-sequence delivery			
	Window Size (Blocks)	4096			
	Payload Size (Bits)	320			
	RLC Header (Bits)	16			
MAC	MAC Header (Bits)	0			
	MAC Multiplexing	Not required for DPCH			
PHY	Physical Channel Type	DPCH			
		Uplink		Downlink	
		Bit Rate (kb/s)	TTI (ms)	Bit Rate (kb/s)	TTI (ms)
		64	20	384	10
				128	20
				64	20
	Transport Block Size (Bits)	336			
	Transport BLER	0 – 30%			
	Error Model	Uniform Distribution			

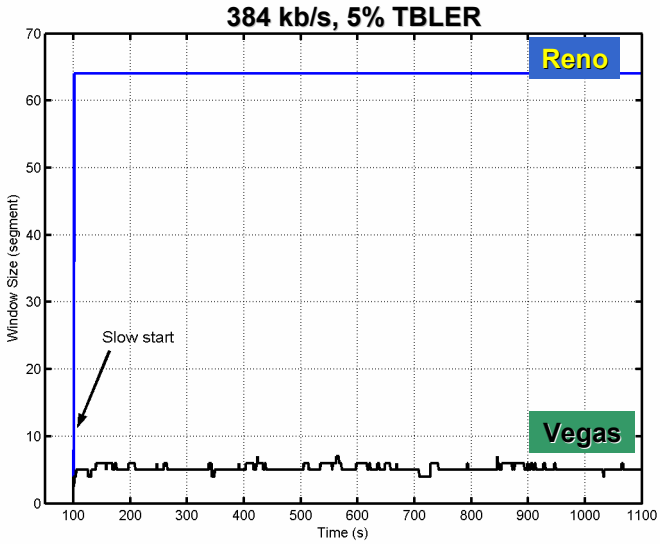
IP Packet Transfer Scenario



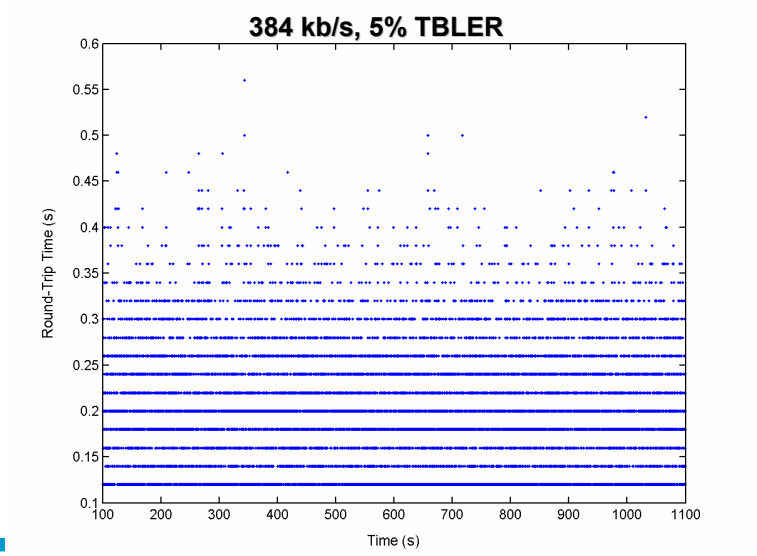
Throughput vs. BLER (FTP Traffic)



TCP Vegas and Reno Congestion Window



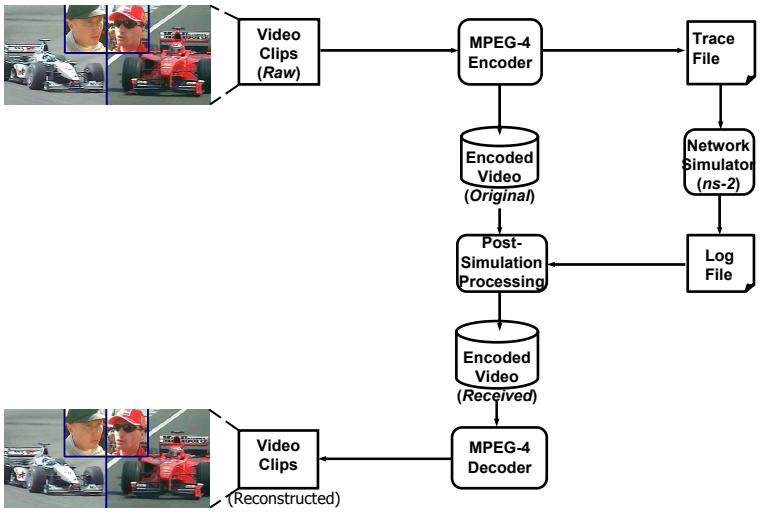
TCP Vegas Round-Trip Time Variability



Mobile Video Streaming

- Streaming: multimedia content is played out without downloading a complete file
- Traffic characteristics:
  - video
    - time-sensitive
    - tolerate lost/erroneous packets
  - data
    - delay-insensitive
    - error-free packets

Streaming Video Model



Demo

'Music' clip

'Container' clip

Summary

- UMTS/WCDMA radio interface gives large round-trip time variations
  - RLC retransmission
  - Transmission time interval
- Vegas' congestion control is very sensitive to the large round-trip time variations:
  - throughput degradation
  - sender window shrinks (but no congestion!)
  - spurious timeout
- Reno's congestion control is insensitive to the large round-trip time variations
  - Performance as expected
- MPEG-4 video streaming
  - RLC retransmission achieves better quality
  - Adaptive and fast RLC ARQ scheme for video