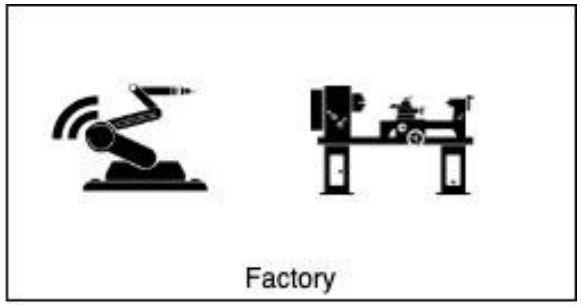
5G R2X Test Bed @ IISc

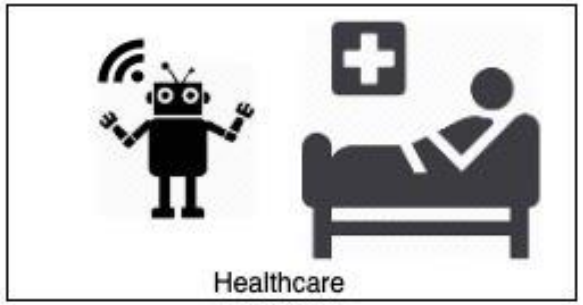
R2X : Robot to Infrastructure

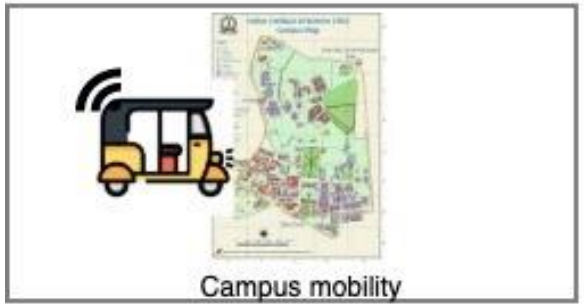
Speaker: Bharadwaj Amrutur, Professor IISc

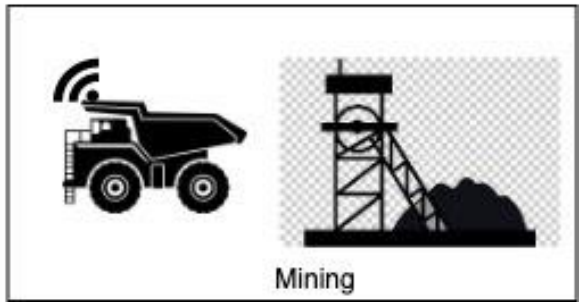
September 2020

Connected Robots and Machines









5G Rel 17 Specifications for URLLC for Mobile Robots (3GPP: TR22014-H30)

Use case	Characteristic parameter				Influence quantity							
	Communication service availability: target value in %	Communication service reliability: mean time between failures	End-to-end latency: maximum	Service bitrate: user experienced data rate	Message size [byte]	Transfer interval: lower bound	Transfer interval: target value (note)	Transfer interval: upper bound	Survival time	UE speed	# of UEs	Service area
Cooperative Robot Control	> 99,9999	~ 10 years	< target transfer interval value	–	40 to 250	– < 25 % of target transfer interval value	1 ms to 50 ms	+ < 25 % of target transfer interval value	target transfer interval value	≤ 50 km/h	≤ 100	≤ 1 km^2
Video based Remote Conrol	> 99,9999	~ 1 year	< target transfer interval value	–	15 k to 250 k	– < 25 % of target transfer interval value	10 ms to 100 ms	+ < 25 % of target transfer interval value	target transfer interval value	≤ 50 km/h	≤ 100	≤ 1 km^2
Standard Mobile Robot	> 99,9999	~ 1 year	< target transfer interval value	–	40 to 250	– < 25 % of target transfer interval value	40 ms to 500 ms	+ < 25 % of target transfer interval value	target transfer interval value	≤ 50 km/h	≤ 100	≤ 1 km^2
Video streaming from Mobile Robot	> 99,9999	~ 1 week	10 ms	> 10 Mbit/s	–	–		–	–	≤ 50 km/h	≤ 100	≤ 1 km^2

Our Current Test Bed (v0.5)

125m

100m

Application Server

EPC S/W on a server

OAI-EPC on a server

WLC

L2 Switch

Custom changes

100Gb L2 Switch

Proprietary API

eNB1

eNB2

eNB3

802.11 n/p

802.11 n/p

802.11 n/p

RRH1

RRH2

RRH3

OAI eNB + Phy (B210)

OAI UE Phy (B210)

.11n/p Dongle

LTE Dongle

Remote Driving Application

- Test Scenario

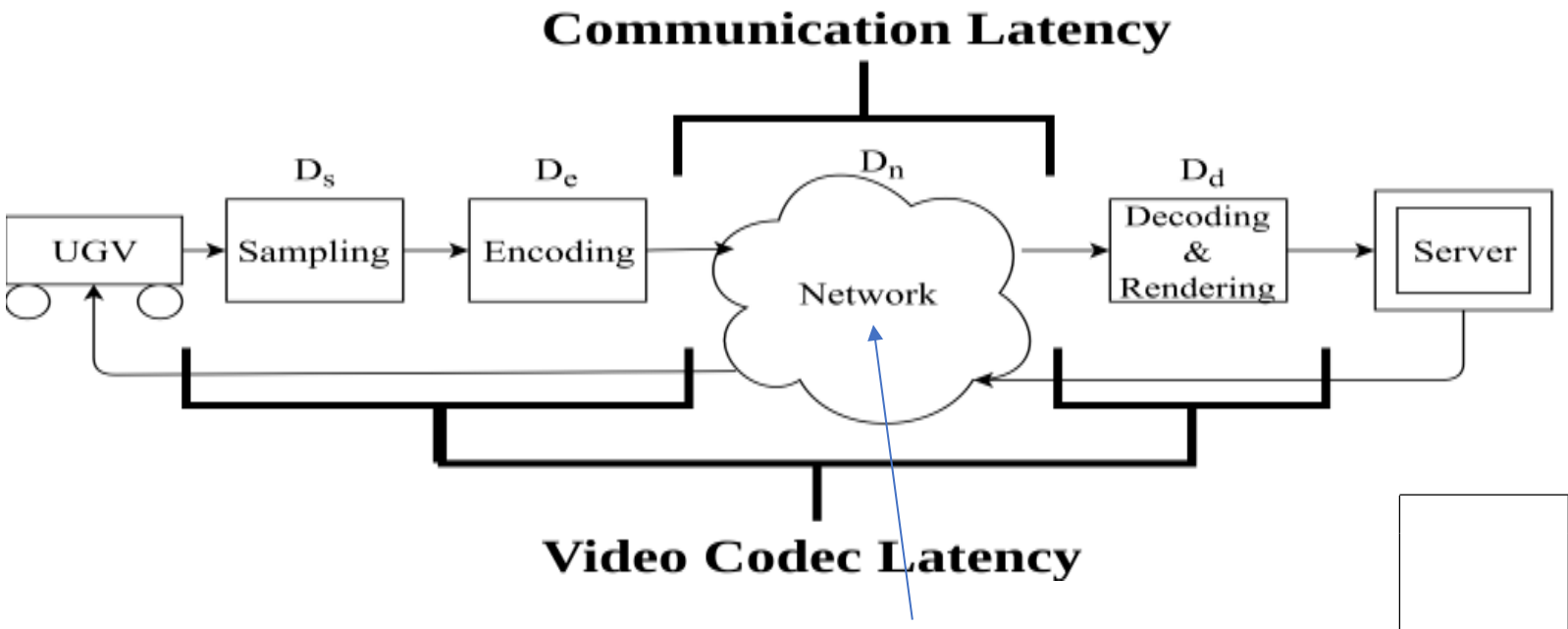
  Emergency Braking

- Latency Bounds
  - 100mS round trip (to meet safe stopping distance criteria)
    - Vehicle camera sensor -> remote driver -> activation of brake

Latency Breakdown & Optimization for 802.11 setup

View from Vehicle's Camera

Braking/Steering Commands



OpenWRT based 802.11 AP (3 No.), with optimized handoffs

End to End latency Components

	Latency value (ms)
Maximum Sampling	33.33
Encoding	13.8 ± 2.79
Network	12.4 ± 3.825
Decoding & Rendering	12.16 ± 3.03
TOTAL	71.68 ± 5.31

Handovers across AP needs attention

	Default (ms)	Optimized (ms)
Scanning	143.88 ± 9.76	54.5 ± 4.47
Roaming	41.75 ± 8.01	26 ± 8.33
TOTAL	186.63 ± 12.32	80.8 ± 8.53

End-to-End optimized Latencies

	Default		Optimized	
	Regular operation (ms)	Handover (ms)	Regular operation (ms)	Handover (ms)
Uplink	210 ± 16.83	396 ± 12.14	71 ± 5.31	149 ± 5.85
Downlink	12 ± 3.45	198 ± 7.55	9 ± 2.93	89 ± 5.67
Processing	13 ± 1.44	13 ± 1.44	13 ± 1.44	13 ± 1.44
TOTAL	235 ± 16.91	606 ± 15.25	93 ± 5.89	251 ± 7.52

[On the Latency in Vehicular Control using Video Streaming over Wi-Fi, Pratik Sharma, et. al., National Conference on Communications 2020]

LTE Optimizations

- Latency and Bandwidth Aware Scheduler within MAC of eNodeB
  - To optimize the allocation of resource blocks
- Larger vehicle (eRickshaw) is being retrofitted for remote driving

eNodeB(3) + EPC

Our Upcoming Test Bed (v1.0) (Mar 2021)

100m

250m

Application

WLC/SDNC

NMS

L2 Switch

Custom changes

Proprietary API

EPC S/W on a server

100Gb L2 Switch

OAI-EPC on a server

eNB1

eNB2

eNB3

OAI eNB + Phy (B210)

802.11 n/p/ax

802.11 n/p/ax

802.11 n/p/ax

RRH1

RRH2

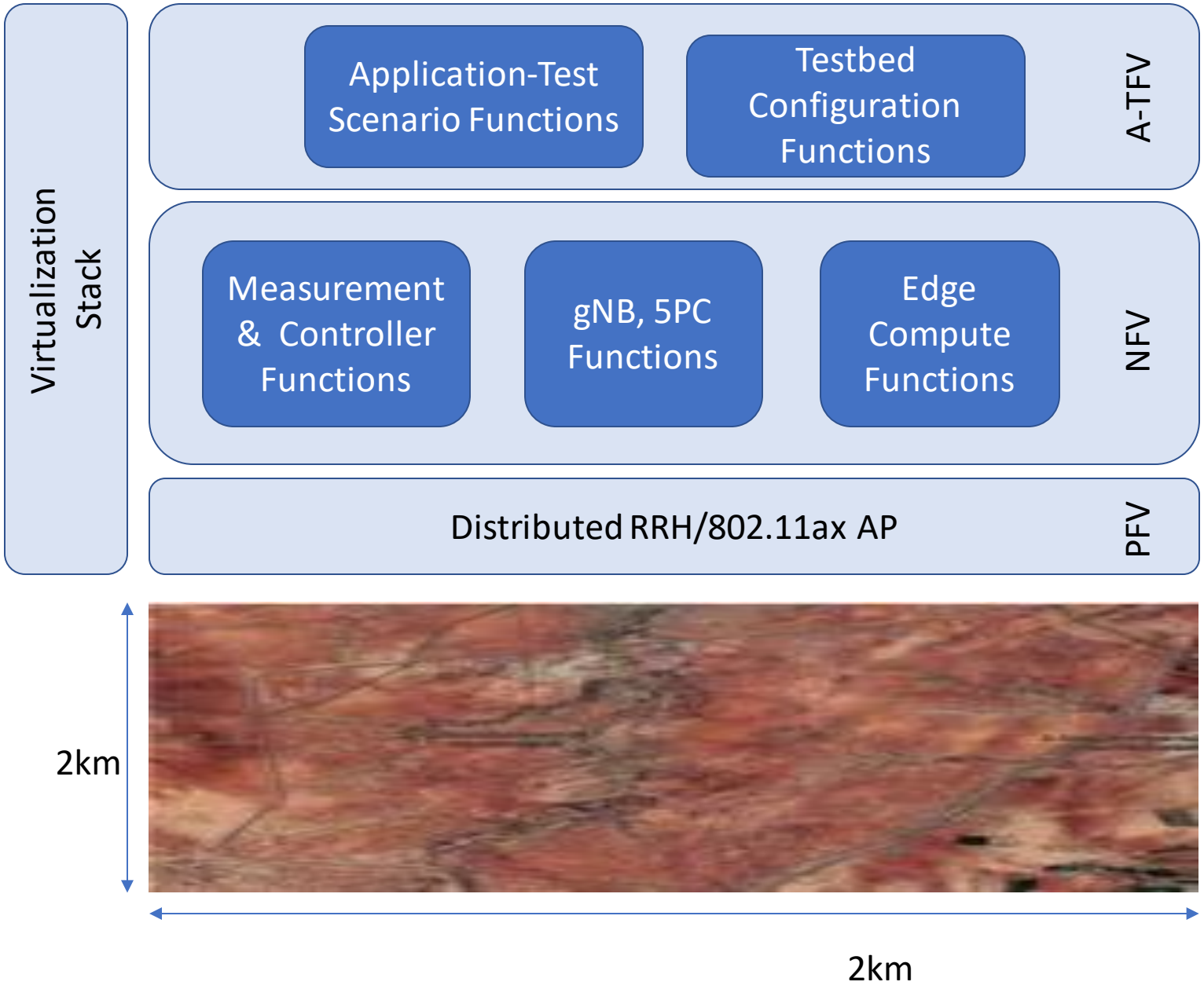
RRH3

.11n/p/ax Dongle

LTE Dongle

OAI UE Phy (B210)

Our Upcoming Testbed (v2.0) (Dec 2021)



Application Research:

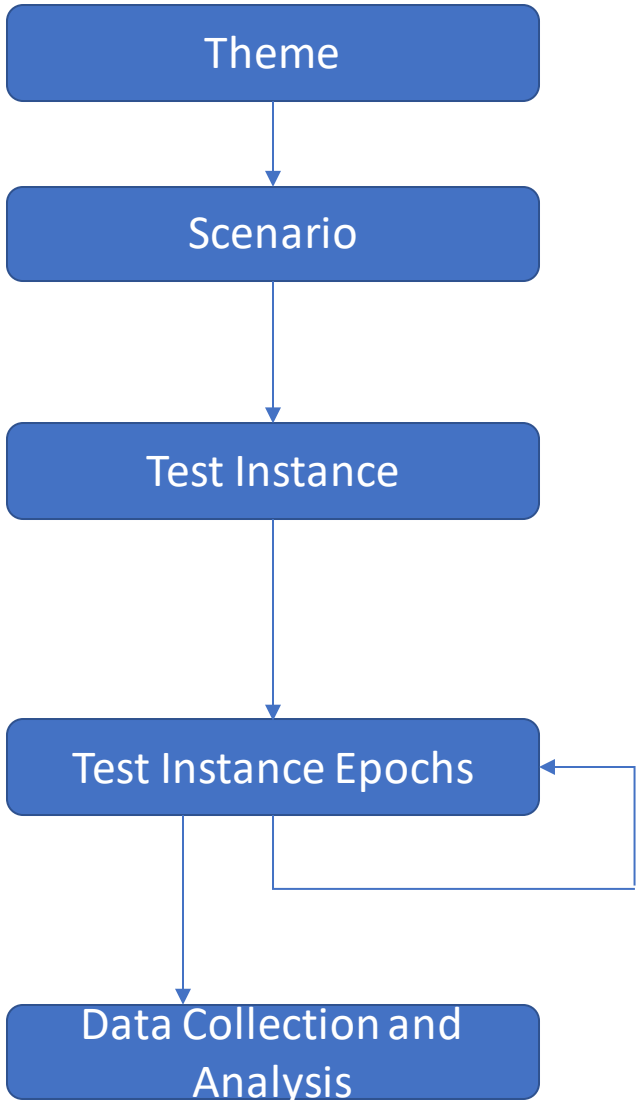
- Unmanned Air Vehicles Systems
- AG Vehicles
- Connected Robots

Technology Evaluation

Pre-Standards Pilots

Precursor to 6G testbed

Automation and Repeatability for Testing



E.g. <Drone Skyways>

<Application scenario, Network scenario, Environment scenario>

E.g. <"Multiple Drones Arriving at an Intersection", "Network setup with two slices", "Radio Interference & Physical Interference">

<"Four Drones with speeds…", "Handover Algo/Scheduler parameters,…", " Multi-path fading + Jamming + Birdy flying in …">

Tests described in High Level Language and Automatically configured onto testbed via SDNC and other APIs

Run Multiple Times to get confidence intervals and reliability measurements

Collaborators

Faculty:

- Bharadwaj Amrutur, Himanshu Tyagi, Aditya Gopalan, Parimal Parag, Chandra Murthy, Neelesh Mehta, K J Vinoy, Varun Raghunathan, K V S Hari, Debasish Ghose, Suresh Sundaram, Ashwini Ratnoo, Omkar S N, Chiranjib Bhattacharyya

Staff & Students

- Pratik Sharma, Srikrishna Acharya, Raghavendra, Bishal Jaiswal, S V R Anand, Dhanaprakash, Varghese Kuruvilla, Poornima, Sadgun Srinivas, Alok Rawat, Ashish Joglekar, Raghu Krishnapuram

Departments:

- Robert Bosch Centre for Cyber Physical Systems, ECE, Aerospace, CSA
- ARTPark (AI & Robotics Technologies Park). @ IISc

Govt. Funding Support:

- Department of Telecommunications, Govt of India
- Department of Science and Technology, Govt of India
- Department of IT & BT, Government of Karnataka

Corporate Funding Support:

- Robert Bosch India, Cisco, Nokia

Current Industry Partners:

CDAC, CDOT, Bosch, Tejas Networks, Cisco, Nokia,

We welcome more partners!

THANK YOU

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