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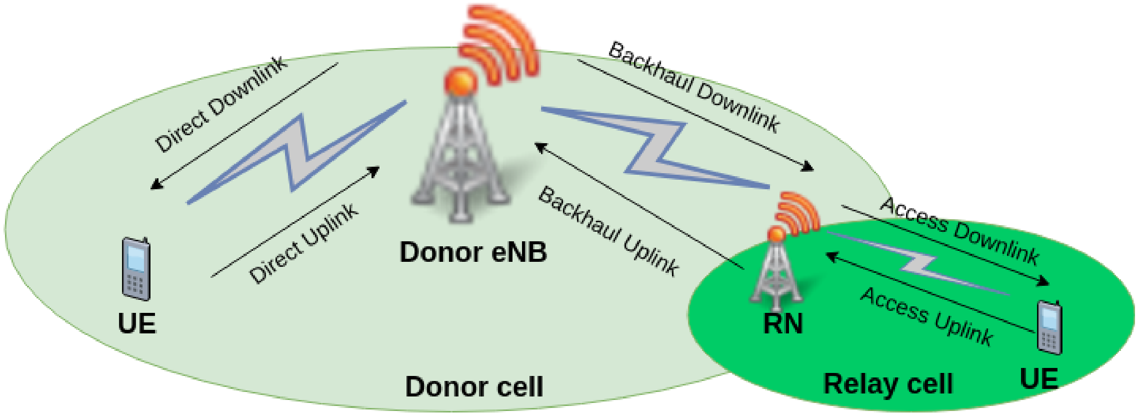

LTE/5G Self-Backhauling with Open Air Interface

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Wireless Networks Group (WNG) @UPC

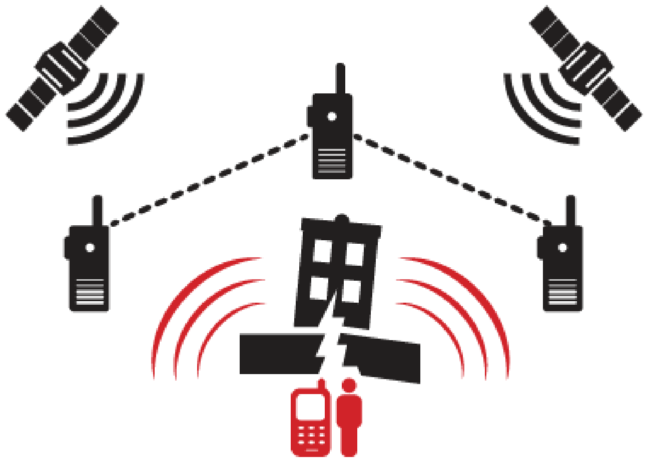
- 7 Faculty Members
- 2 Postdocs, 10 PhD students
- Standardization works @IETF, IEEE 802.11
- +50 R&D projects completed

Softwarized Cellular Networks @WNG

- OpenBTS (2G)

RESCUECELL

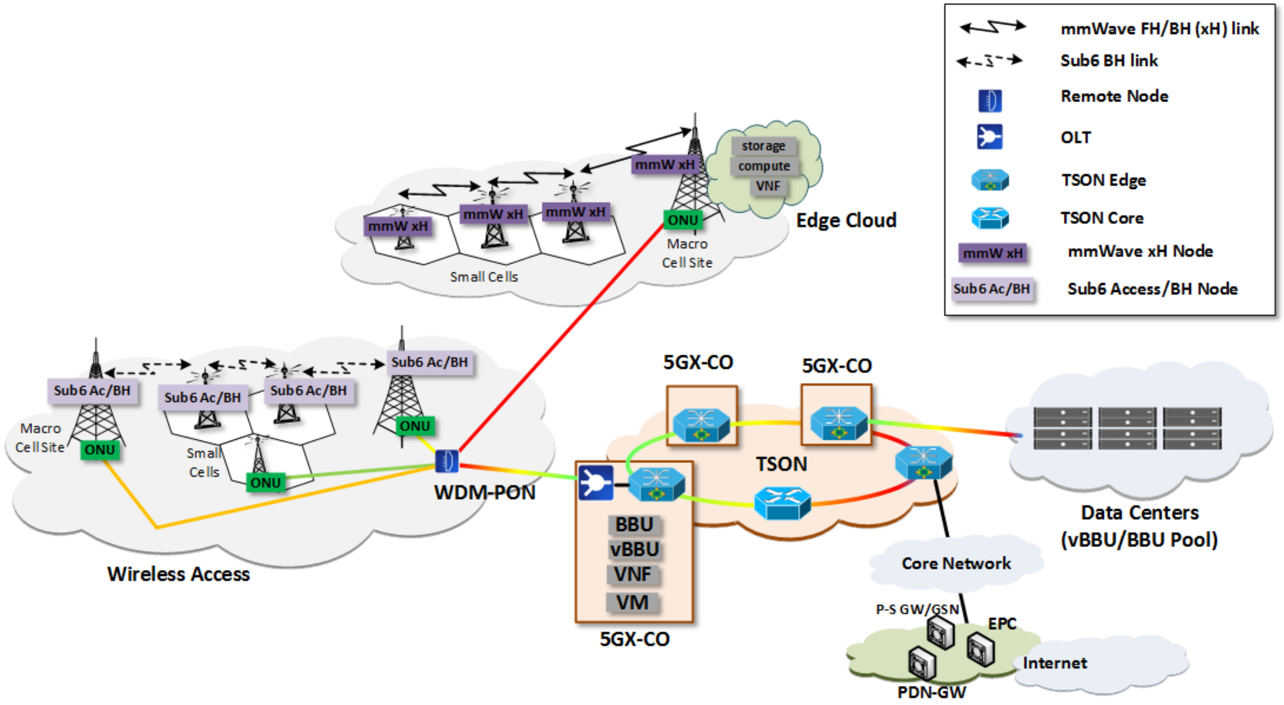
SEVENTH FRAMEWORK PROGRAMME



- OpenUMTS (3G)
- Open Air Interface (4G)

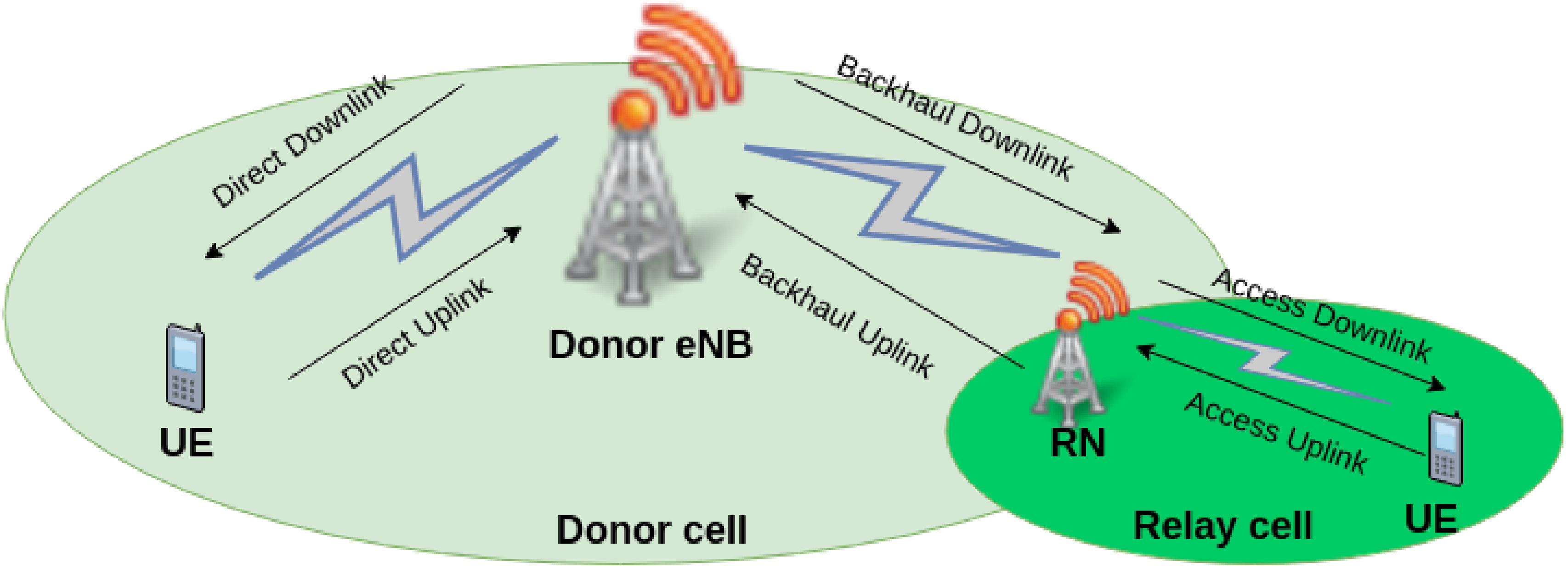
OAI @WNG

- LTE-WiFi Aggregation (LWA)
- SDN integration (OVS, OF) to OAI
- Wireless LTE Backhauling



LTE/5G Self-Backhauling

- The access and the backhaul links share the wireless channel resources



LTE/5G Self-Backhauling: Why?

- Physical limitations for wired BH
- To reduce CAPEX/OPEX
  - Wireless cheaper than fiber
  - Use of same radio hardware for access/BH
  - Same O&M systems
- Higher spectrum efficiency
  - Reuse of wireless channel resources
- New applications:
  - Cells on wheels, Drone BS, etc.

LTE/5G Self-Backhauling: Challenges

- Resource scheduling between access and BH
- Access-BH interference
  - Less problematic for mmWave-based access/BH considered in 5G
- FH capacity/delay requirements
  - New functional splits relaxes these requirements

Scientific Literature on Self-BH

- Enhanced UEs (eUEs) [1] to relay eNB traffic, by forwarding L2/MAC packets
  - Requires significant changes at UE
  - Incentive and cooperation mechanism for battery-powered UEs to relay traffic for eNBs are challenges
- Enhanced evolved NodeB (e2NB) [2] targets a wireless mesh between e2NBs
  - Defines virtualized UEs@eNB, each communicating with a neighbor eNB
  - MME and HSS components of EPC is also included in e2NB to allow standalone functioning
  - The developed solution is experimented with an LTE emulator/simulator, showing its feasibility
  - Requires changes at eNBs, calls for a copy of HSS to individual eNBs (with the UEs that can connect), not 3GPPP-compliant
  - No physical experimentations

[1] A. Apostolaras et al., ``Evolved user equipment for collaborative wireless backhauling in next generation cellular networks," *IEEE SECON*, 2015.
[2] R. Favraud, N. Nikaein, ``Wireless Mesh Backhauling for LTE/LTE-A Networks," *IEEE MILCOM 2015*, pp. 695-700, Oct. 2015.

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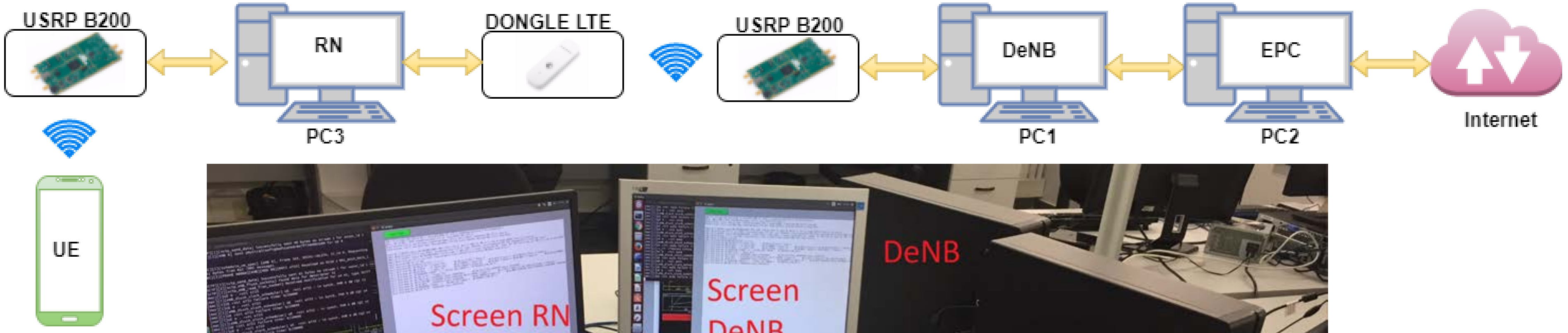
LTE Self-Backhauling in 3GPP

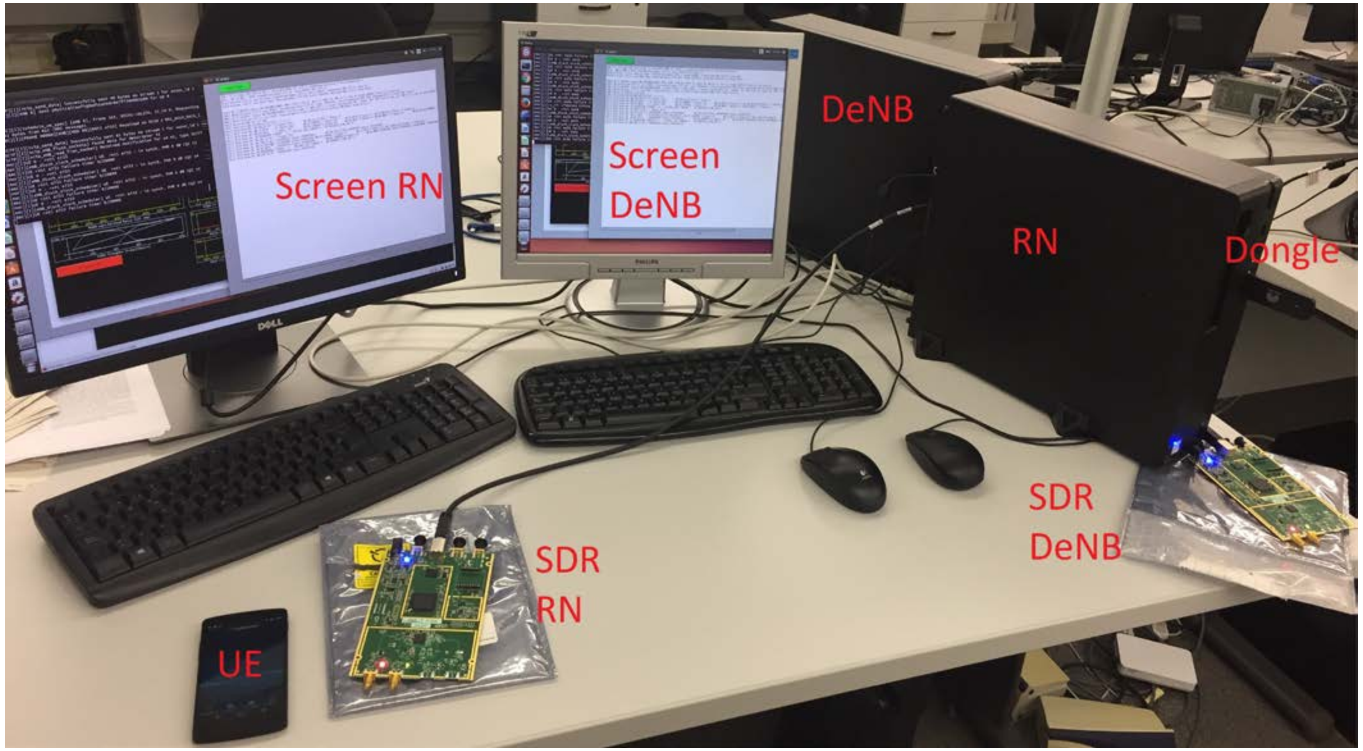
- To extend the radio coverage or increase the capacity of 4G networks, the concept of *relaying* was defined in Rel. 10

	Half-duplex	Full-duplex	L2 Relay
Inband	**Type 1**	**Type 1b**	**Type 2**
Outband		**Type 1a**	

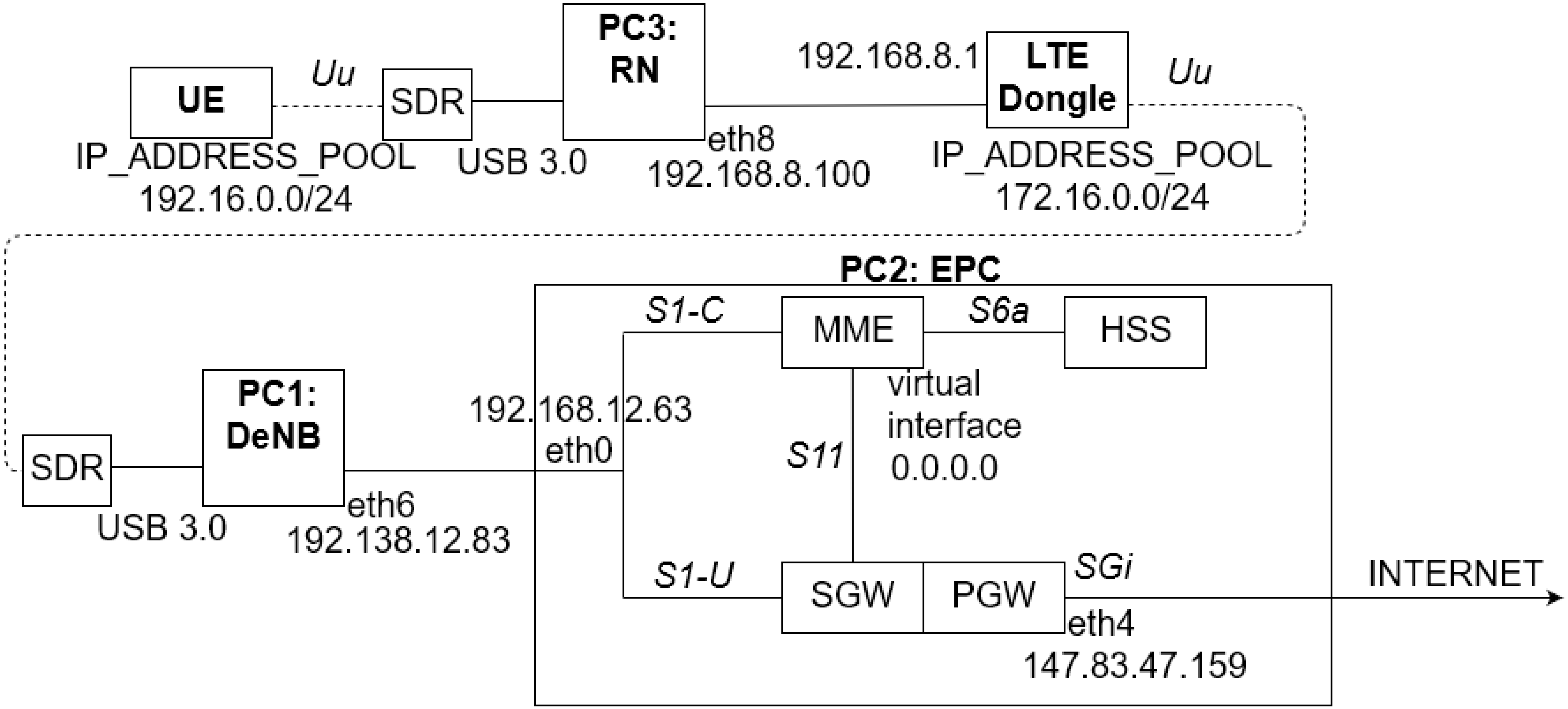
- RN has to have UE functionality towards DeNB
- The uptake of *relaying* has been limited
  - Due to the densification targets of the operators (e.g., through small cell deployments), there is a fresh interest in wireless backhauling solutions

Self-BH Implementation

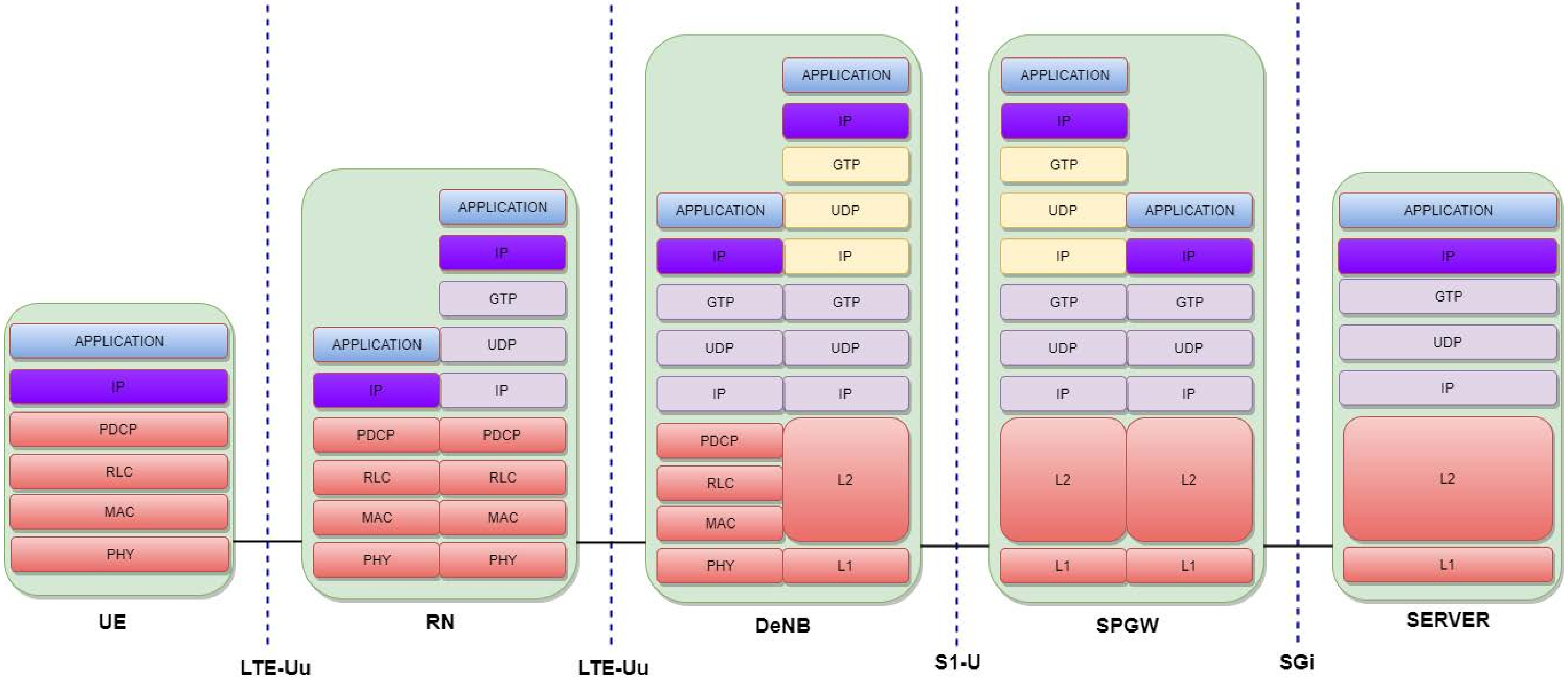




Network Configuration



Double GTP Encapsulation Problem



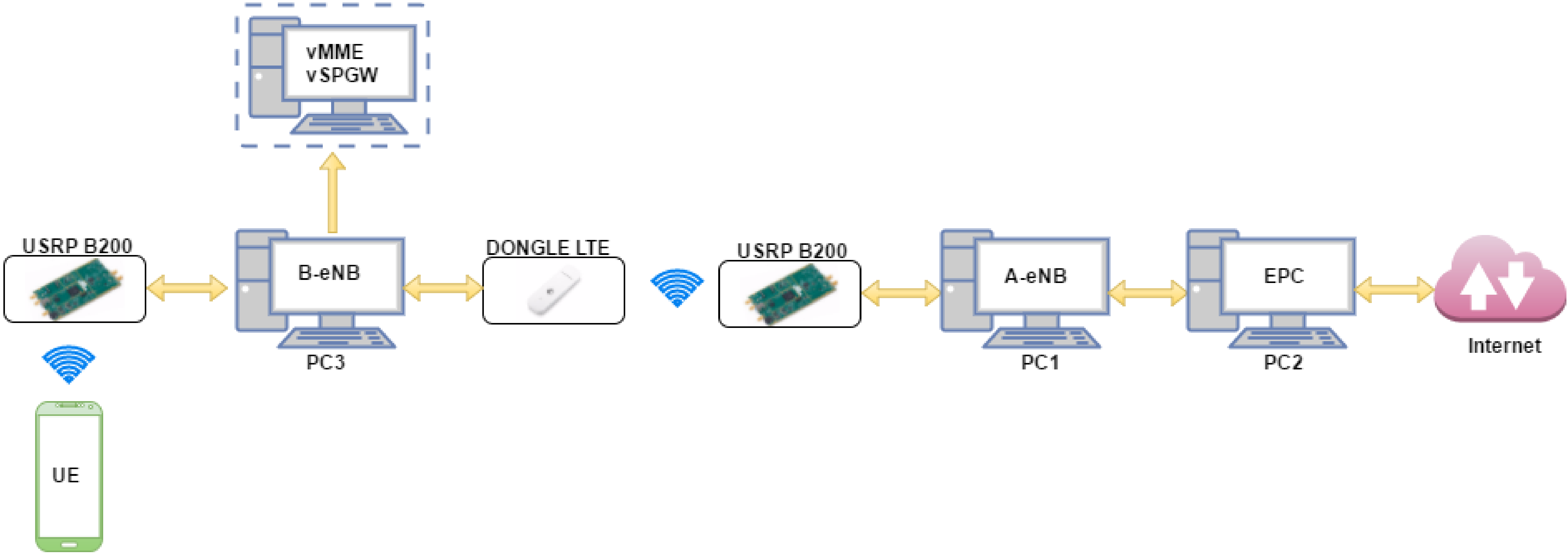
Double GTP Encapsulation: Wireshark

Packets @ S-GW

No.	Time	Source	Destination	Protocol	Length	Info
312	102.949234211	172.16.0.2	8.8.8.8	GTP <DNS>	115	Standard query 0x139a AAAA accounts.google.com
313	102.980839445	8.8.8.8	172.16.0.2	GTP <DNS>	143	Standard query response 0x139a AAAA accounts.google.com AAAA 2a00:1450:4003:804::200d
374	105.455194580	172.16.0.4	8.8.8.8	GTP <GTP <DNS>>	160	Standard query 0xfeaa AAAA s.gateway.messenger.live.com
375	105.483206227	172.16.0.4	8.8.8.8	GTP <GTP <DNS>>	148	Standard query 0xeee0 AAAA dsn9.d.skype.net
376	105.785206524	172.16.0.4	8.8.8.8	GTP <GTP <DNS>>	148	Standard query 0xe0f9 A mtalk.google.com
377	105.825197449	172.16.0.4	8.8.8.8	GTP <GTP <DNS>>	158	Standard query 0xc585 A android.clients.google.com
378	105.845198557	172.16.0.4	8.8.8.8	GTP <GTP <DNS>>	162	Standard query 0x8f7f AAAA mobile.pipe.aria.microsoft.com
379	106.315233897	172.16.0.4	8.8.8.8	GTP <GTP <DNS>>	155	Standard query 0xf077 A youtubei.googleapis.com
380	107.115198702	172.16.0.4	8.8.8.8	GTP <GTP <DNS>>	156	Standard query 0xb645 A www.googleadservices.com
381	107.195278487	172.16.0.4	8.8.8.8	GTP <GTP <DNS>>	147	Standard query 0xac77 A cast.google.com
382	108.985241669	172.16.0.4	8.8.8.8	GTP <GTP <DNS>>	166	Standard query 0xe786 AAAA 288.0.26.7.20703.rst12.r.skype.net
383	110.455278575	172.16.0.4	8.8.4.4	GTP <GTP <DNS>>	160	Standard query 0xfeaa AAAA s.gateway.messenger.live.com

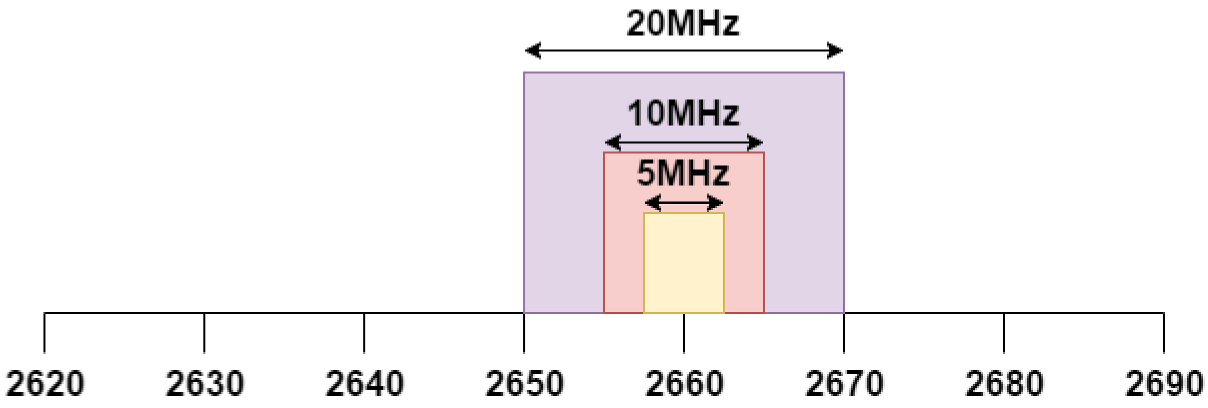
```
> Frame 374: 160 bytes on wire (1280 bits), 160 bytes captured (1280 bits) on interface 0
> Ethernet II, Src: Giga-Byt_4c:e2:7b (1c:1b:0d:4c:e2:7b), Dst: Dell_cc:50:fb (00:1e:4f:cc:50:fb)
> Internet Protocol Version 4, Src: 192.168.12.83, Dst: 192.168.12.63
> User Datagram Protocol, Src Port: 2152, Dst Port: 2152
> GPRS Tunneling Protocol
> Internet Protocol Version 4, Src: 172.16.0.2, Dst: 192.168.12.63
> User Datagram Protocol, Src Port: 2152, Dst Port: 2152
> GPRS Tunneling Protocol
> Internet Protocol Version 4, Src: 172.16.0.4, Dst: 8.8.8.8
> User Datagram Protocol, Src Port: 65516, Dst Port: 53
> Domain Name System (query)
```

Final Implementation

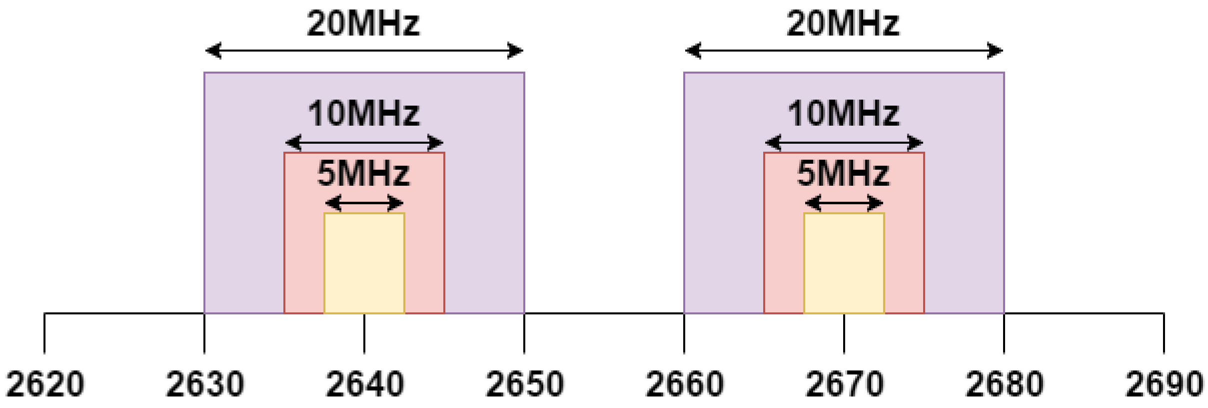


Inband vs. Outband Frequency Settings

Conventional LTE Network and In-band Self-backhauling

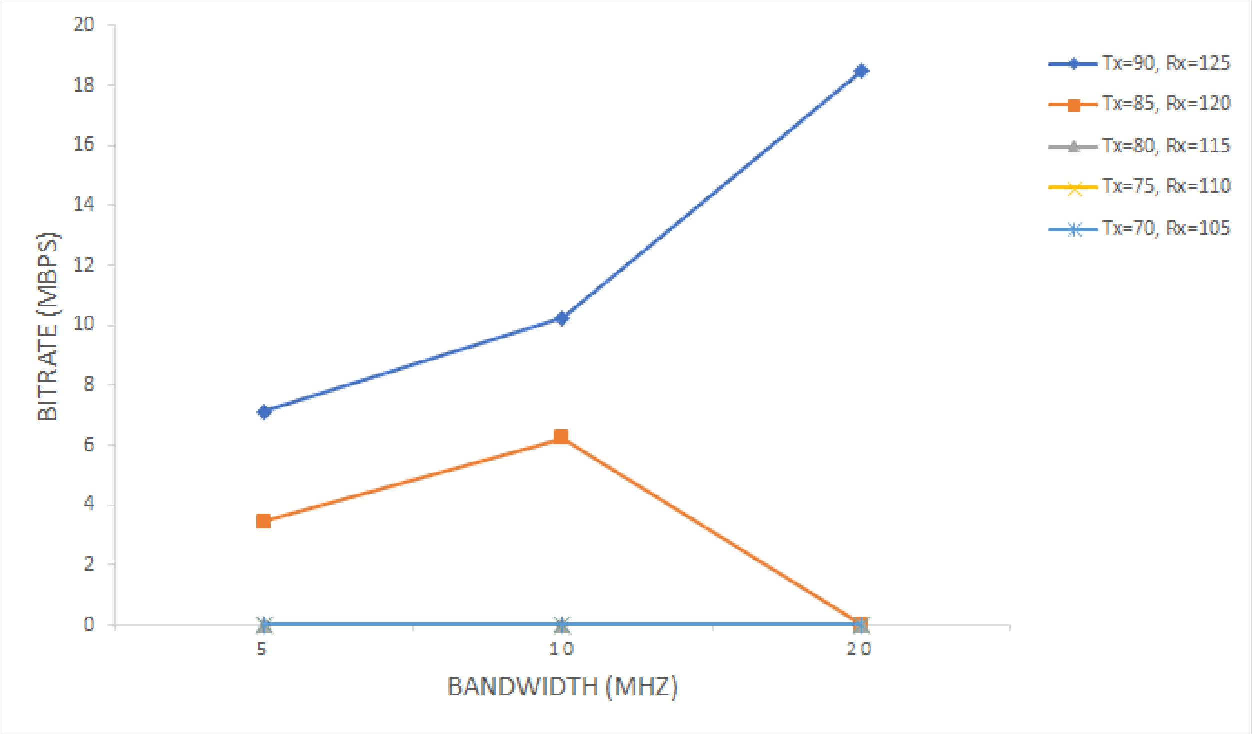


Out-band Self-backhauling

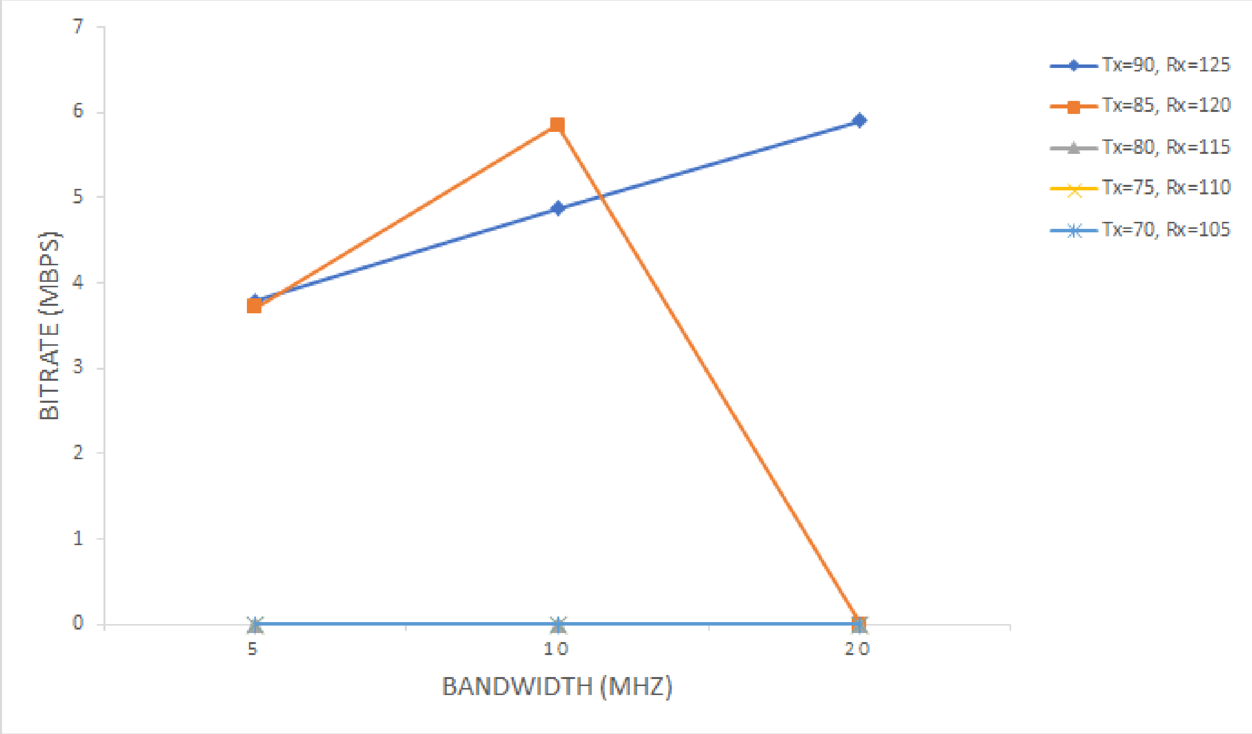


Conventional LTE Setup Performance

Downlink

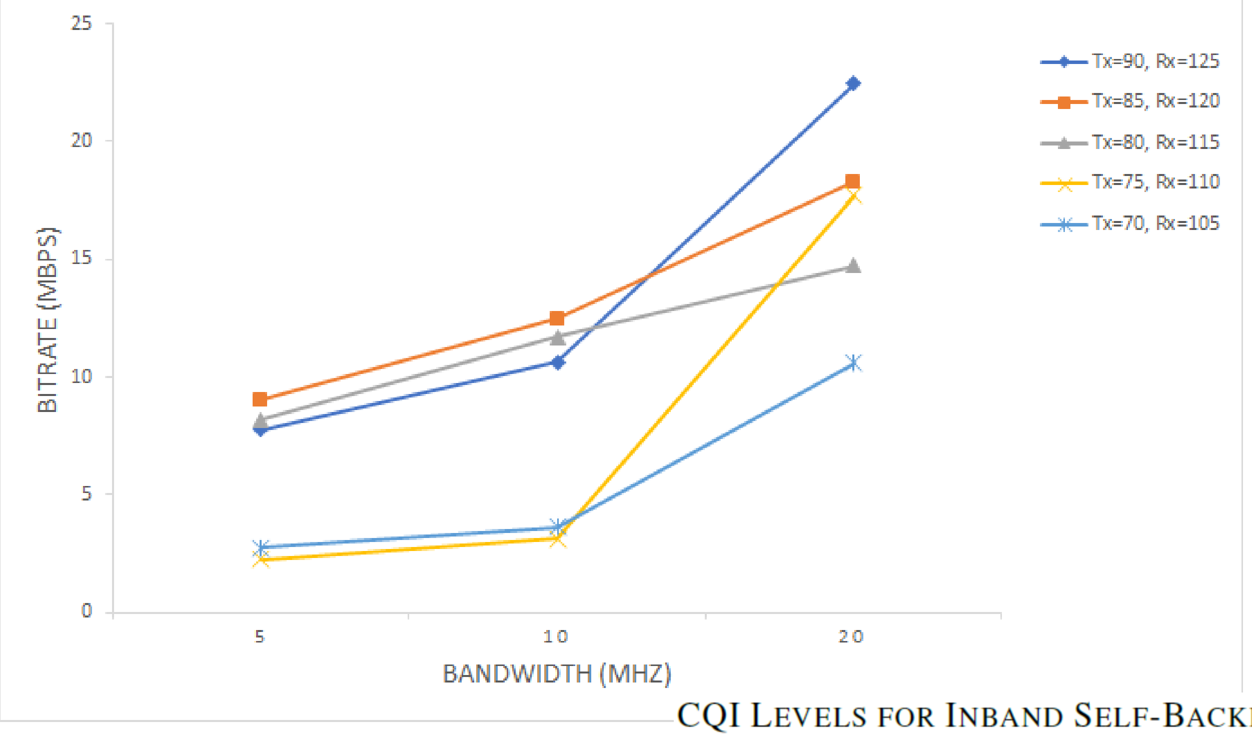


Uplink



Self-Backhauling: Type 1b RN

Downlink



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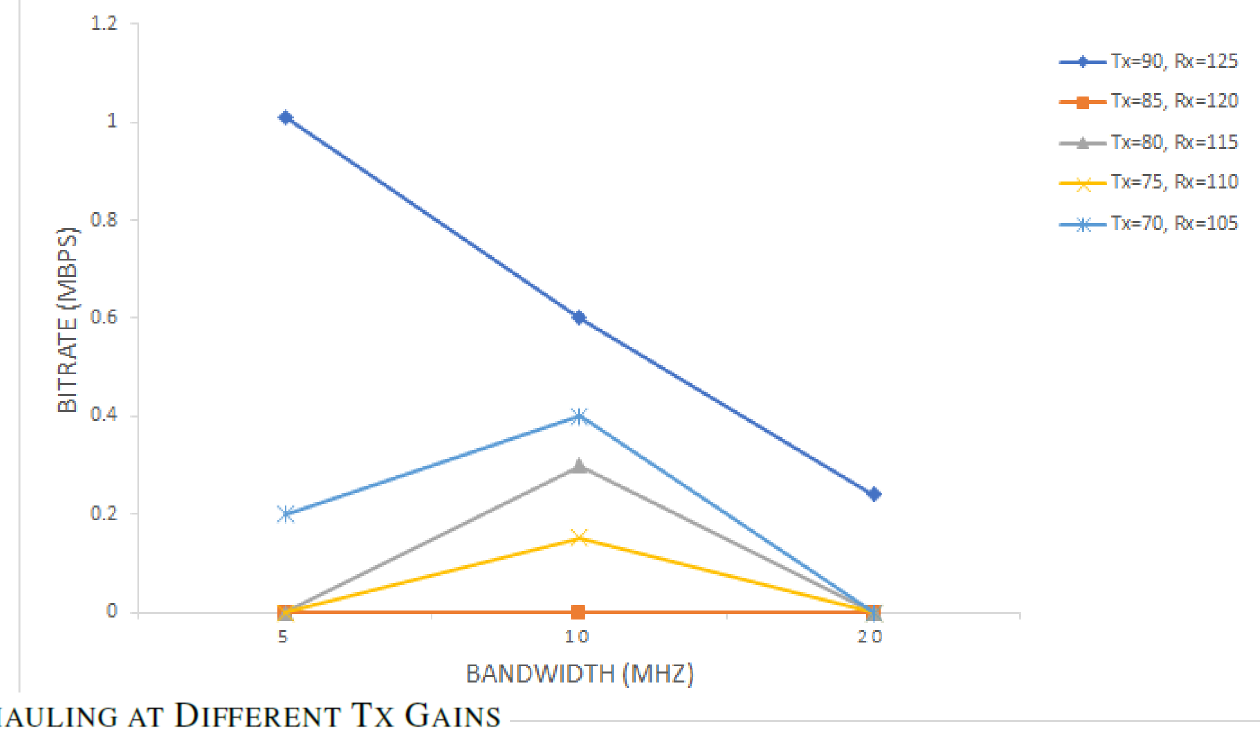
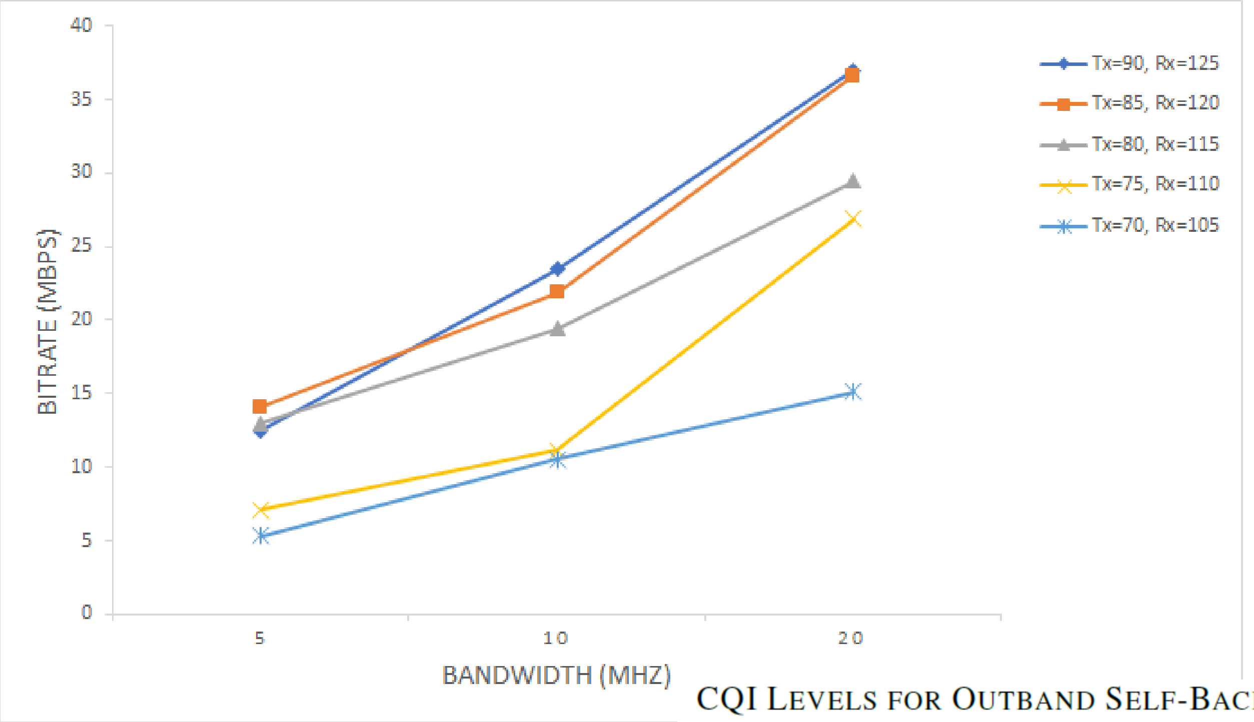


CQI LEVELS FOR INBAND SELF-BACKHAULING AT DIFFERENT TX GAINS

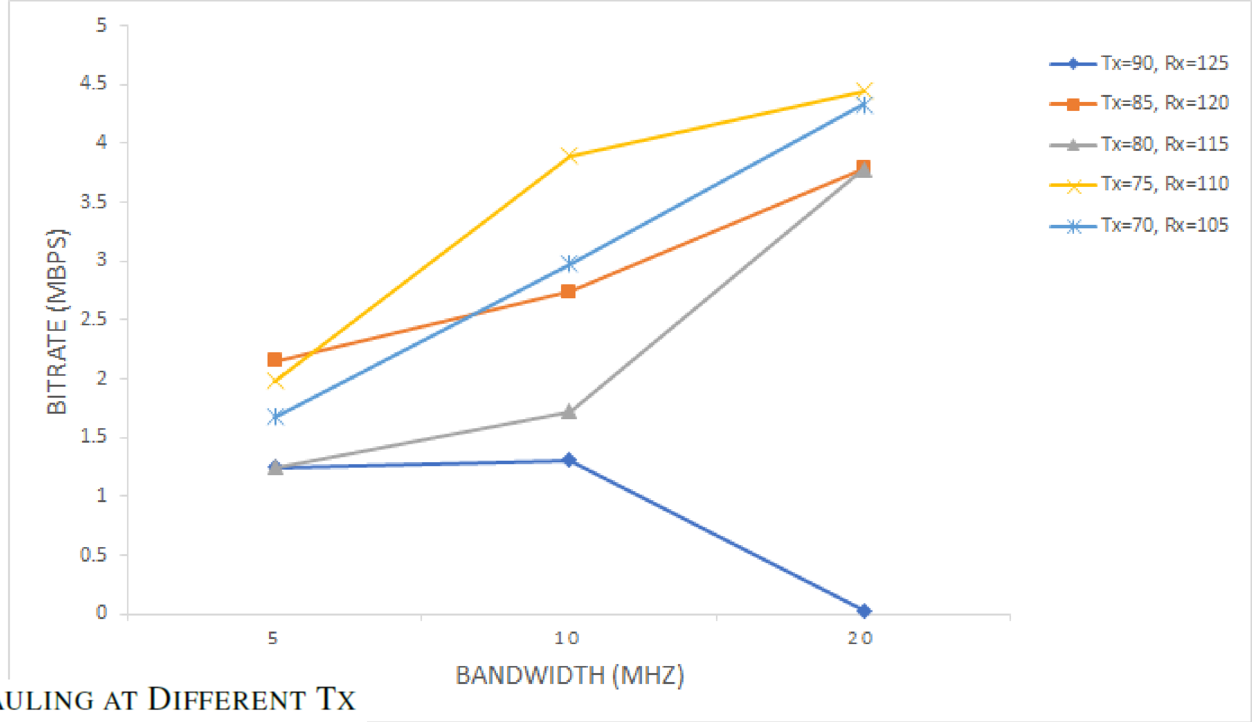
Bandwitdh (MHz)	DeNB Gain (dB)					RN Gain (dB)
	70	75	80	85	90	75
5	9	10	12	14	14	13
10	8	10	10	12	14	11
20	6	8	9	11	13	10

Self-Backhauling: Type 1a RN

Downlink



Uplink



CQI LEVELS FOR OUTBAND SELF-BACKHAULING AT DIFFERENT TX GAINS

Bandwitdh (MHz)	DeNB Gain (dB)					RN Gain (dB)
	70	75	80	85	90	75
5	9	11	12	14	15	13
10	8	9	11	13	14	12
20	7	8	10	12	14	11

Conclusions

- Self-Backhauling can extend the radio coverage and network capacity of the LTE networks
- Better performance enhancements are expected in a real setup with more idealistic antenna setups
- Access-BH interference is a challenge
  - In mmWave access and BH, interference will be less of a challenge
- A potential future work is the efficient scheduling of resources for inband (Type 1 or 1b) RN solutions