Dynamic Traffic-Adaptive Topology Reconfiguration in 5G Optical Hybrid Fronthaul Networks

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Motivation

- With the wide deployment of RRHs in 5G, the number of existing fiber links used for fronthaul connection is limited. Connectivity among RRHs and between BBU and RRH cannot be guaranteed.
- The existing fibers used for fronthaul connection may not be enough to provide certain level of protection.
- Many adavanced technologies are avaibable for 5G fronthaul/backhaul networks.

Available 5G Fronthaul/Backhaul Technologies

Technology	Options	Upstream throughput	Downstream throughput	Latency/ Jitter	Distance	Note
Microwave PtP †	PtP	1 Gbps	1 Gbps	< 1 msec/ hop	2-4 km	6-60 GHz remote not-spot
Microwave PtmP †	PtmP	1 Gbps	1 Gbps	< 1 msec/hop	2-4 km	6-60 GHz peppered capacity
Satellite †	LOS	15 Mbps	50 Mbps	300 msec one-way latency 5-30 msec jitter	~ubiquitous	due to cost per Mbps realistic Tput 2-10 Mbps DL/1-2 Mbps UL
TVWS †	NLOS	18 Mbps/ch	18 Mbps/ch	10 msec	1-5 km	up to 4 channels up to 10 km at 10 Mbps using 2 ch with LOS
mmWave 60 GHz †	LOS	1G bps	1 Gbps	200μ sec	1 km	scalable
mmWave 70-80 GHz †	LOS	10 Gbps	10 Gbps	65-350μ sec	3 km	scalable
Sub-6GHz 800 MHz-6 GHz †	NLOS	170 Mbps	170 Mbps	5 msec single hop one way	1.5-2.5 km urban 10 km rural	licensed (20 MHz TDD) expected to increase to 400 Mbps
Sub-6 GHz 2.4, 3.5, 5 GHz †	NLOS	150-450 Mbps	150-450 Mbps	2-20 msec	250 m	unlicensed data rate depends on MIMO
FSO ‡	LOS	10 Gbps	10 Gbps	low	1-3 km	

Jaber, Mona, et al. "5G Backhaul Challenges and Emerging Research Directions: A Survey." *IEEE Access* 4 (2016): 1743-1766.

Free Space Optics (FSO)

- Free-space optical communication (FSO) is an optical communication technology that uses light propagating in free space to wirelessly transmit data for telecommunications or computer networking. "Free space" means air, outer space, vacuum, or something similar. This contrasts with using solids such as optical fiber cable or an optical transmission line.

- An FSO link uses the free space between a pair of line-of-sight laser photodetector transceivers to transport data. The FSO beam has a wavelength in the micrometer range, yielding advantages in terms of free license, interference immunity, and high capacity, among others

- The quality of the FSO links depends on several factors, such as transmission distance, power, and weather cond/itions

Current Works

- [1] proposed a hybrid 5G fronthaul architecture which utilize technologies such as Optical Fiber (OF), Free-Space Optics (FSO), millimeter-wave (MMW) to construct the network.
- [2] designed a cost-effective solution to upgrade pre-5G cellular backhaul equipped with pre-deployed OFs using FSO links and mirror components while guaranteeing K-disjoint paths for each node pair.
- [3] developed a unique network modeling and simulation environment that integrates realistic dynamic obscuration scenarios, autonomous topology reconfiguration algorithms and enhanced link state routing protocols.

[1] Pham, Anh T., et al. "Hybrid free-space optics/millimeter-wave architecture for 5G cellular backhaul networks." *Opto-Electronics and Communications Conference (OECC), 2015*. IEEE, 2015.

[2] Li, Yuan, et al. "Optimization of free space optical wireless network for cellular backhauling." *IEEE Journal on Selected Areas in Communications*33.9 (2015): 1841-1854.

[3] Llorca, Jaime, et al. "Optimizing performance of hybrid FSO/RF networks in realistic dynamic scenarios." *Optics & Photonics 2005*. International Society for Optics and Photonics, 2005.

In summary

- Existing works mostly focus on new 5G fronthaul architecture, and fronthaul/backhaul network planning given static traffic.
- Existing dynamic version focuses on FSO link characteristics such as weather disruption, channel degradation, and channel blocking. Works focusing on traffic dynamics are lacking

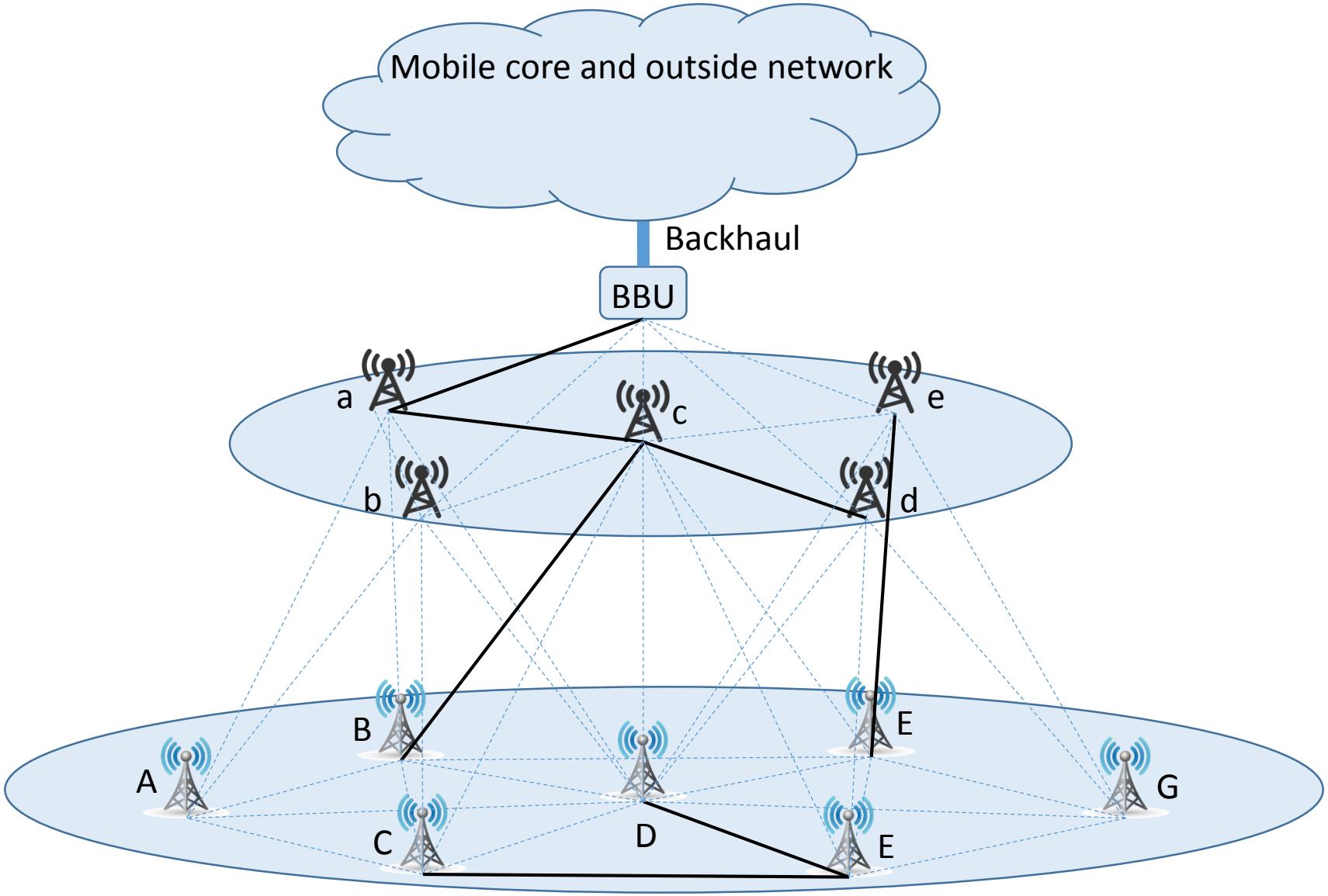
Problem Statement (Dynamic)

- **Given:**
  - A sequence of traffic requests (We assume that there is only one traffic request coming at a time)
  - Traffic types: (1) upstream (from RRH to BBU) (2) downstream (from BBU to RRH)
  - Existing fiber links and potential FSO links and their capacities (to have a potential FSO link between two nodes, they must be separated within the transmission range)

- **Objective:**
  - Minimize the number of FSO links in use

- **Constraints:**
  - Accommodate all traffic requests coming in sequence
  - Provide shared/dedicated protection for each primary working path

Hybrid Architecture



Goals

- Propose 2-3 dynamic heuristics to perform network reconfiguration.
- Compare them with the optimal solution. (Optimal solution generates min # of FSO links in use, but it might disrupt many working flows during reconfiguration)
- Discuss the tradeoff between the # of disrupted flows and the number of FSO links in use