Self-organized Cooperative 5G RANs with Intelligent Optical Backhauls for Mobile Cloud Computing

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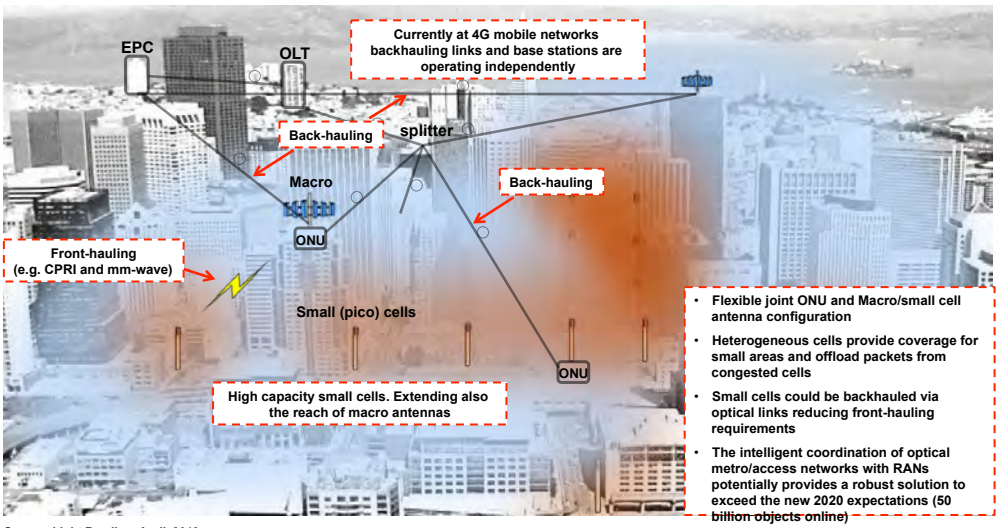
Outline

- Motivation for joint coordination between optical and wireless networks
- Proposed network architecture featuring cooperative CRANs and IP backhauling
- Joint radio and optical resource management
- Self-organized RANs with spatiotemporal capabilities
- Initial system level modeling of heterogeneous cells
- Conclusions

Motivation for joint coordination



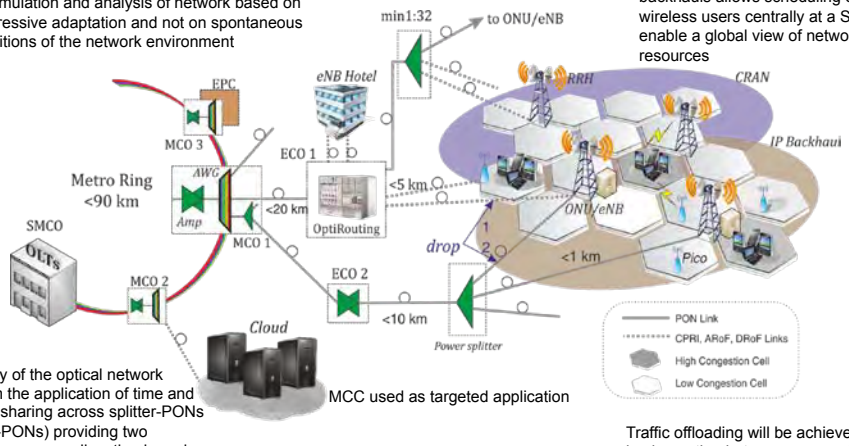
- Flexible joint ONU and Macro/small cell antenna configuration
- Heterogeneous cells provide coverage for small areas and offload packets from congested cells
- Small cells could be backhauled via optical links reducing front-hauling requirements
- The intelligent coordination of optical metro/access networks with RANs potentially provides a robust solution to exceed the new 2020 expectations (50 billion objects online)

Source: Light Reading, April, 2013

Proposed network architecture

Self-organisation that involves adaptive beamforming will be exploited through the accumulation and analysis of network based on progressive adaptation and not on spontaneous conditions of the network environment

Dynamic bandwidth allocation and routing algorithms, with the optical backhauls allows scheduling of the wireless users centrally at a SMCO to enable a global view of network resources



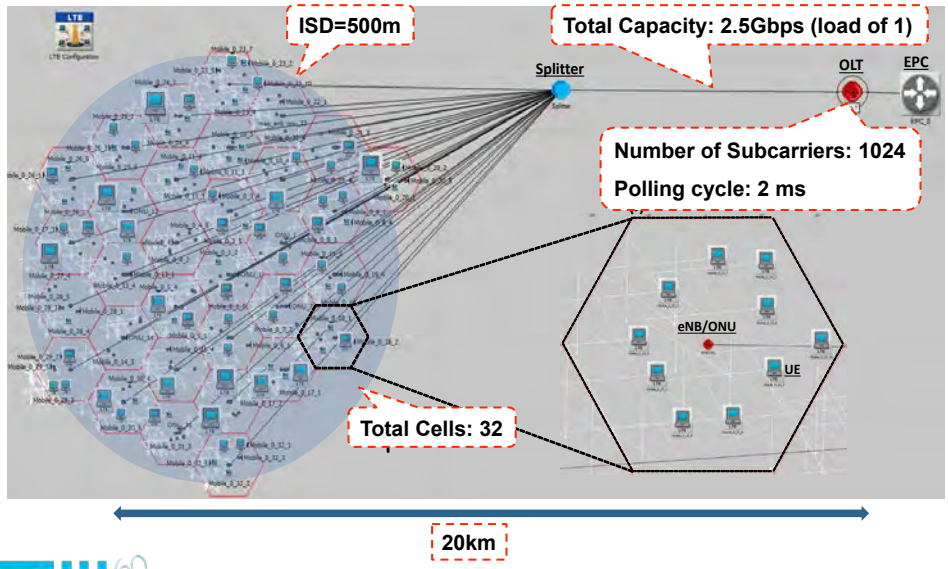
The flexibility of the optical network derives from the application of time and wavelength sharing across splitter-PONs (i.e. TWDM-PONs) providing two dimensional resource allocation based on bandwidth demand

MCC used as targeted application

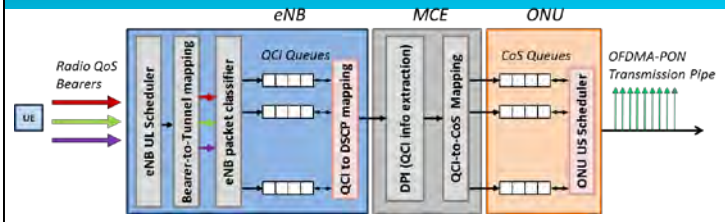
The architecture exploits an efficient inter-eNB communication via centralised RAN (CRAN) and low-cost inter-connection links with traditional IP backhauling

Traffic offloading will be achieved by implementing heterogeneous wireless connections of pico, femto and relay antennas

Joint radio and optical resource management



Optical and wireless queue mapping for IP backhauling



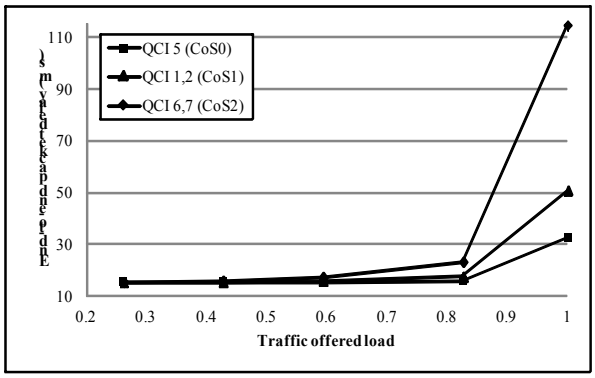
W. Lim, et. al. "Dynamic Subcarrier A llocation for 100 Gbps, 40 km OFDMA-PONs With SLA and CoS", *JLT, 2013*
W. Lim, et. al., "Flexible QoS Differentiation in Converged OFDMA-PON and LTE Networks", OFC (OTh4A), 2013
W. Lim, et. al., "QoS mapping for LTE b ackhauling over OFDMA-PONs", I CTON, 2012
ACCORDANCE (WP4 and WP5)

- An effective mapping mechanism between ONUs and eNBs is required
- The MCE implements a mapping scheme between PON CoS queues and LTE QCIs
- The MCE first performs Deep Packet Inspection (DPI) to extract the QCI information from the arriving packets and then consults a predefined mapping table to decide on the CoS
- Multiple QCI queues can be mapped to a single CoS queue, or even have a 1-1 mapping among them

Mapping distribution

Parameters	*Description*			
Total network capacity	*2.5 Gbps*			
Number of ONU/eNBs	*32*			
Number of OFDMA subcarriers	*1024*			
Network reach	*20 km*			
Inter site distance (ISD)	*500 m*			
Number of cells	*32*			
Mobility of UE	*50 km/h*			
Polling cycle	*2 ms (fixed)*			
Traffic offered load 1.0	*2.5 Gbps*			
Number of bearers per UE	*5*			
QoS mapping between LTE QCIs and optical queues	*QCI*	*Percentage of traffic*	*Priority*	*Optical queue*
	5	*20%*	*High*	*CoS0*
	1	*40%*	*Middle*	*CoS1*
	2			*CoS1*
	6	*40%*	*Low*	*CoS2*
	7			*CoS2*

End-to-end Packet Delay Evaluation



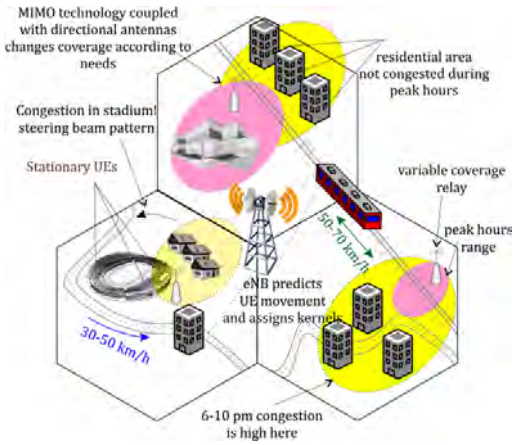
- Algorithms developed to prioritize the transmission of the high priority queues
- CoS0 has been assigned a higher weight compared to other queues and therefore above 80% of the traffic load the delay of CoS0 grows significantly lower than in CoS1and CoS2.
- CoS0 and CoS1 exhibit delays of less than 30 and 50 ms, respectively when the network operates at maximum capacity

Self – organized network functionalities

- Analyse moving patterns of UEs and devise statistical model (e.g. Bayesian Network)
- Location detection is based on cooperative time of arrival (ToA) algorithms
- Detect congested zones in the network and analyse patterns
- The network does not make spontaneous decisions based on current congestion, but gradually adjusts the coverage of its individual transceivers (eNBs, relays, pico) in anticipation of congested areas
- Through adaptive algorithms the SMCO converges to the network form that provides the best resource allocation
- This is deemed very important in the context of MCC, as the number of nodes is expected to increase and—as a result—congestion phenomena will pose a significant challenge

Spatiotemporal Database and Channel Estimation

- Channel equalization data are collected throughout the operation of the network
- A database of de-convolution impulse responses (IRs) is devised that combats channel conditions for discrete locations
- The system detects if there is no improvement in the error correction and steps back, ensuring that the de-convolution has always a positive contribution
- This database is updated in regular time intervals at the eNB hotel (for the RRHs), as well as the individual ONU/eNBs

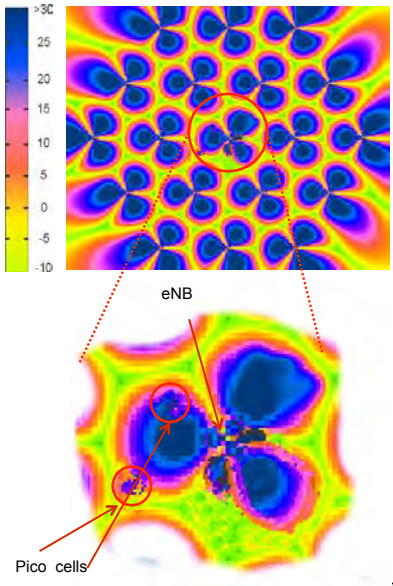


System level model developments in MATLAB

- Cellular layout: Hexagonal grid, 19 cell sites, with BTS in the corner of the cell 65-degree sectored beam
- The SONs comprise heterogeneous elements (e.g. macro, pico) that each time form the optimum configuration
- Adaptive algorithms decide the parameters of individual elements of the heterogeneous network according to predicted demand

Parameters	Value (Macro)	Value (Pico)
Typical Intersite Distance (ISD)	500 m	100 m
Frequency	2 GHz	2 GHz
Distance Dependent Pathloss (R in km)	$L=128.1+37.6log_{10}(R)$	$L=38+30log_{10}(R)$
Antenna Height	20 m	2 m
Max Tx Power	46-49 dBm	24-28 dBm
Bandwidth	10 MHz	10 MHz
Antenna gain	15 dBi	0 dBi – 2dBi

[Similar to TR 136 931 V9.0.0]



Conclusions

- Optical-wireless convergence is described, taking into consideration not only the aggregated bandwidth of the ONU/eNBs, but also the individual bandwidth requirements of wireless users
- Better resource management, reduced delay, and scalable optical links is achieved via long-reach NGPONs, as well as a combination of centralized and decentralized backhauls
- The solution tackles bandwidth outage with dynamic routing at the intersection of the presented heterogeneous backhaul networks (CRAN and IP backhauling), as well as with redundant links
- The network is able to constantly adjust to the conditions of the RAN in terms of channel estimation and bandwidth demands due to comprehensive monitoring and analysis of UE channel conditions
- System level models have been developed accounting for heterogeneous cell deployment
- Initial results for joint optical and resource management have confirmed less than 30 ms delay of high-priority QCIs 5 even at the highest network load
- On-going investigation will involve further development of the system level model to account for self-organization and thorough performance evaluation of MCC over the proposed platform