Virtual Cells versus Small Cells for In-Building Radio Planning

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***Abstract*—The emergence of mobile broadband technology provides a valuable service for users to transfer media content, surf the internet, and stream video on their mobile. Higher data-rate capability depends on a strong signal from a base station and capacity from the network. 70-90% of wireless high data-rate demand is located inside buildings. A traditional macro base stations thin capacity blanket is insufficient to deal with high data rate in-building users because of the poor signal penetration inside buildings and subsequently lower user link budget. The lower link budget of the in-building users creates a higher battery drain on the handsets. A dedicated wireless system is often installed inside the building or close to the building to address the poor outdoor-to-indoor propagation property of an in-building environment. Small Cells and Distributed Antenna System (DAS) are preferred deployment options for optimal coverage and capacity requirements. A unique approach is a Virtual Cell, which is an Intelligent DAS (IDAS) with capacity routing capability. A Virtual Cell can assign capacity on demand and improve the link budget of the user. In this paper, Small Cell and Virtual Cell performances are compared in an LTE downlink context. It will show that a Virtual Cell has higher usable capacity than a Small Cell with no inter-cell resource block coordination. In addition, the throughput data rates of the two systems converge in hot spots. The Virtual Cell has a capacity scalability since all the Base Station resources are centralized.**

***Index Terms*—Small Cell, Virtual Cell, Distributed Antenna System, Indoor-Planning.**

I. Introduction

Wireless and mobile network operators face the continuing challenge of building networks that effectively cope high data-traffic growth rates and revenue erosion. Wireless technology standards are evolving towards higher bandwidth requirements for both peak data rates and cell throughput growth . Since 70-90% of wireless user's data-transfer occurs indoors [1], coverage and capacity is critical. Higher data-rates require a strong signal strength to interference plus noise (SINR) ratio. There are several ways to provide in-building coverage and the most common approach is to use a traditional macro cell deployment [2]. The penetration loss of the building limits the signal quality from a macro cell and is inadequate to provide sufficient data rates to in-building users for wireless data services [3].

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To address this, a dedicated, in-building wireless system is preferred for greater coverage and capacity [4].

Another impact of the arrival of broadband mobile communications is the increase in data traffic, which requires more capacity from the network. This can be achieved by using more spectral bandwidth, increasing the number of base station cells or access points, increasing the spectral efficiency and using load balancing techniques.

Small Cell and DAS solutions are mainly affected by the traffic demands and spectral efficiency. DAS is comprised of many remote antenna ports distributed over a large area and connected to a single base station by fiber, CAT 6, coax cable or microwave links. Without advanced signal processing techniques in the DAS, the same downlink signal is broadcast on all of its antennas, also known as simulcast. Studies show that simulcasting is an effective means to combat shadowing in noise-limited environments due to transmitter macro diversity [5]. Indoor DAS can help enhance the coverage and SINR when compared to Small Cells for the same transmit power [6].

Small Cell is a cost-effective alternative to extend in-building coverage and capacity. The number of Small Cells is typically equivalent to the number of remote antennas in DAS. However, one of the challenges with Small Cell deployment is the severe inter-cell interference: Small Cell system performance is significantly degraded without any interference management [7]. Another challenge with Small Cell deployment is the increased number of hand-offs, which can lead to poor quality of service and a high signaling load for the mobility management of the network. Hand-offs occur when a user is transferred from one cell to another based on which cell has the stronger signal. Since each Small Cell provides a limited capacity, the areas with high user density need to be provisioned to provide sufficient users' average busy hour throughput plus some headroom. Over provisioning of the Small Cells will lead to inefficiencies in the deployment of resources and, ultimately, additional costs.

DAS has a number of advantages: centralization of base station resources; neutral host compatibility, modulation independent, and higher SINR over the coverage area [8]. An IDAS system, which has the ability to alter the simulcast ratio via load balancing, has a high spectral efficiency as well as a data throughput performance equivalent to that of a Small Cell at a hot spot. The terminology used to define an IDAS node is a Virtual Cell. A Virtual Cell is a remote node that has access to a base station with adequate and scalable resources, potentially located in a Base Station Hotel.

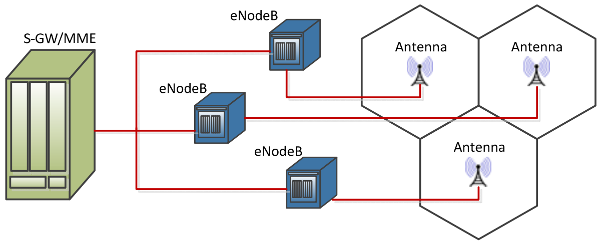


Fig. 1. Three Small Cells configuration

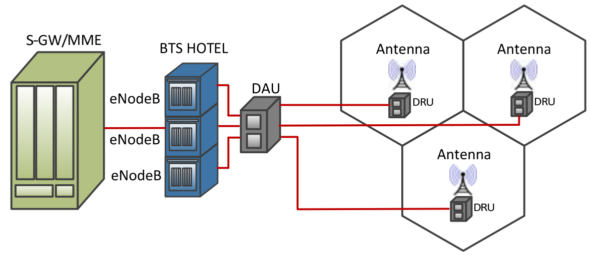


Fig. 2. Virtual Cells configuration

A Virtual Cell will have the added advantages of scalability of BTS resources. The Base Station Hotel can be viewed as a Local Cloud. When the remote units have access to all of the system's resources, there is no need to add new base stations or bandwidth for higher capacity requirements in hotspot areas. If more capacity is required, additional resources or base stations can simply be added at the head-end central location. Moreover, in a distributed network architecture, where all resources are centralized, multi-band and multi-operator scenarios can easily be accommodated. The Base Station Hotel resources that are centrally available can be routed to the remote Virtual Cells via the distributed network.

A Virtual Cell deployment has a constant cost for a given geographical area irrespective of the frequency bands and operators.

In this paper, the performance of a Virtual Cell and a Small Cell in-building deployment in the downlink LTE is investigated. The purpose is to compare the performance in terms of useable capacity, spectral efficiency per cell and throughput.

Long Term Evolution (LTE) is enhanced in Universal Terrestrial Radio Access (UTRA) and is capable of providing higher data rates, improved spectral efficiency and many more innovative features, which overcome the problems associated with increased data traffic. LTE uses multicarrier Orthogonal Frequency Division Multiplexing (OFDM) for the downlink. OFDM is an effective method to overcome the problem of multipath delay spread. LTE supports data modulation schemes QPSK, 16QAM, and 64QAM in the downlink. The scheduler in an eNodeB (base station) allocates resource blocks (RB), which are the smallest elements of resource allocation to the users.

II. In-Building Wireless Solution

In this section, we will introduce Small Cell and Virtual Cell deployment solutions for in-building wireless systems.

A. Small Cell

Small Cells are small base stations that deliver capacity to a small coverage area. Small Cells are scaled down eNodeBs that are limited by the number of carriers, bands and DSP resources it can support and provide coverage in hot-spots or in-building as compare to macro cells [9]. With a Small Cell deployment, the total system bandwidth requirements increase proportionally to the number of nodes. However, having more nodes also increases the inter-cell interference, which in turn reduces the achievable spectrum efficiency per user. The placement of the Small Cell nodes has a significant impact on the system performance [10]. This includes increased signalling, ports on the MME, S-gateway and Network Management databases. The basic Small Cell architecture can be seen in Fig. 1.

B. Virtual Cell

The basic Virtual Cell distributed network architecture consists of a BTS Hotel with multiple remote units as seen in Fig. 2. In a traditional DAS architecture the remote units are connected to the centrally located BTS and the downlink signal is broadcast to all the cells. Similarly, in the uplink direction, the received signals from the different remote units will be combined at the base station [11]. The division of the coverage area into smaller cells results in improved performance through minimal path loss and optimized transmission power. With the use of multiple antennas, the path loss decreases and less downlink power from the base station is required to cover the same area. Similarly, less uplink power from the mobile unit is required to communicate with the DAS remote units, thereby improving the mobile battery life. In DAS, several remote antenna elements are connected to an eNodeB through a fiber optic cable, LAN cabling or microwave link via a Digital Access Unit (DAU), as shown in Fig.2. The remote antenna elements are identified as Digital Remote Units (DRUs) in Fig. 2.

A Virtual Cell is a remote node that has access to all of the system's resources at the base station. The Base Station resources can be routed to the remote Virtual Cells via the distributed network. As an example, sectors can be routed to a particular Virtual Cell or carrier frequency bands could be activated at a particular cell, independent of the other Virtual Cells.

III. Case Study Description and Simulation Parameters

We considered a two-ring hexagonal cellular system with nineteen remote antenna units, as depicted in Fig. 3, wherein the distance between antennas is set at 50 meters for In-Building cases.

The Small Cell architecture requires an individual eNodeB for each antenna unit. The simulations of the Virtual Cell architecture are based on two distinct scenarios: 1) VC1, seven central antennas (Ant 1, 2, …,7) are supported by one eNodeB , 2) VC2, three different groups of antennas ({Ant 1, 6 and7},{Ant 2 and 3}{Ant 4 and 5}) are separately connected to three eNodeBs, 3) VC3, three different groups of antennas ({Ant 1, 6 and 7},{Ant 2}{Ant 3, 4 and 5}) are separately connected to three eNodeBs. VC1 is a traditional DAS implementation with a 1:7 simulcast ratio.

The performance of the Small Cell and Virtual Cell architectures is analyzed through system level simulations. An

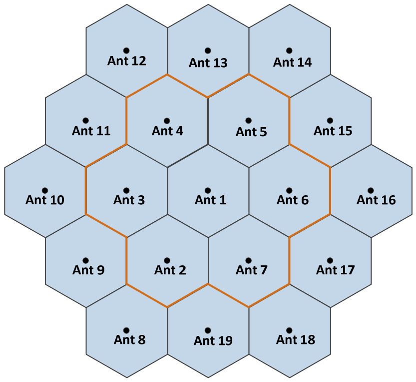


Fig. 3. Structure of hexagonal cellular system.

eNodeB allocates the available RBs to UEs by estimating the signal and uplink power level of the UEs. The simulation system parameters, as shown in TABLE I, are chosen to investigate the technical performance of the various architectures. The conclusions of this paper are independent of the transmitted power, inter-antenna distance and carrier frequency.

At a given *TTI* (Transmission Time Interval) for the LTE simulation, the eNodeB in a cell gathers the CQI (Channel Quality Indicator) information of UEs and allocates the frequency RBs to each UE, using various scheduler techniques.

- **Path-loss Model:** The propagation model is used to predict the path loss for in-building scenarios. The In-building path-loss model is a simple model that calculates the path loss of the indoor environment under ideal conditions. Path loss is usually expressed in *dB*. In its simplest form, the path loss can be calculated using the formula:

$$L = 10n\log_{10}(d) + 20\log_{10}(4\pi f) + c \qquad (1)$$

  where *L* is the path-loss in *dB* and is represented by the path-loss exponent *n*=3.76 for the in-building simulations. *d* is the distance between the transmitter and the receiver, measured in kilometers, *c* is a constant which takes into account the system losses and *f* is the carrier frequency.

- **Received Signal Strength (RSS):** Received Signal Strength is usually expressed in *dBm*. In its simplest form, the RSS can be calculated using the formula:

$$RSS(dBm) = P_{Tx}(dBm) - L(dB) \qquad (2)$$

  where RSS is the received signal strength in *dBm*, P_{Tx} is antenna transmission power and *L* is the path-loss in *dB*.

IV. Comparison of Results for Small and Virtual Cell

A. SINR Distribution for Different Solutions:

Signal to Interference plus Noise Ratio is usually expressed in *dB*. In its simplest form, the SINR can be calculated using the formula:

$$SINR = RSS - RISS - N_{th} \qquad (3)$$

TABLE I. Simulation Parameters

PARAMETERS	VALUE
Channel Bandwidth	5 *MHz*
Carrier Frequency	2.14 *GHz*
FFT size	1024
Number of Resource Blocks	25
Subcarrier Spacing	15 *kHz*
Cellular Layout	Hexagonal grid, 19 Antennas
Inter-Antenna Distance	50 meters
Propagation loss	$128.1+37.6\log_{10}(R(km))$
White Noise Power Density	-174 *dBm/Hz*
Scheduling	Proportional Fair, Max-Min
TTI	1 *ms*
Transmission scheme	SISO
Antenna Transmission Power	25 *mW*
Noise Figure	10 *dB*

where SINR is signal to interference plus noise ratio, RISS is received interference signal strength and N_{th} is Thermal Noise in *dB* which is calculated as follows:

$$N_{th} = N_{th-density} - 30 + 10\log_{10}(BW) + NF \qquad (4)$$

where $N_{th-density}$ is white noise power density in *dBm*, *BW* is bandwidth in *Hz* and *NF* is noise figure in *dB*.

The SINR with respect the remote antenna configuration is shown in Fig. 4. Red represents the largest SINR and blue represents the weakest SINR. The SINR distribution of each scenario is presented to highlight the inter-antenna interference and it can be seen that the best downlink SINR coverage is achieved with VC1. This is expected because there is no inter-antenna interference amongst the 7 central antennas with VC1. The Small Cell architecture, however, has the worst SINR distribution, because of the inter-antenna interference. No interference coordination between the Small Cells is assumed, as this would impact the useable capacity. In the VC2 scenario, the simulcast ratio is smaller than in VC1 and the cells are grouped together and fed by a unique eNodeB. The VC3 scenario would be used in a Hot Spot application whereby an entire eNodeB resource would be allocated to one remote unit.

Figure 5 shows the SINR distribution of each solution in terms of CDF: 43%, 56% and 65% of coverage area has a SINR less than 10 dB in VC1, VC2 and Small Cell, respectively.

B. Link Performance Model

The link performance model specifies the Block Error Rate (BLER) at the receiver end, giving a certain resource allocation and Modulation and Coding Scheme (MCS). 15 unique MCS levels are classified for LTE, which are associated with 15 CQI values. The CQIs use coding rates between 1/13 and 1 when integrated with QPSK, 16-QAM and 64-QAM modulations. A

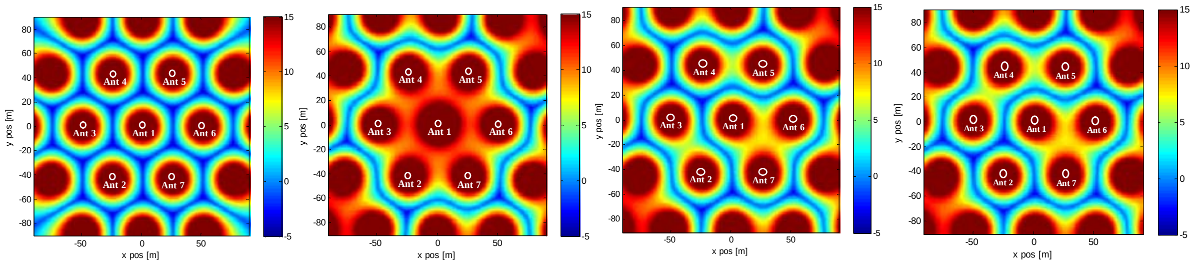


Fig. 4. SINR distribution of different solutions- Small Cells (left), VC1 (middle-left), VC2 (middle-right), VC3 (right)

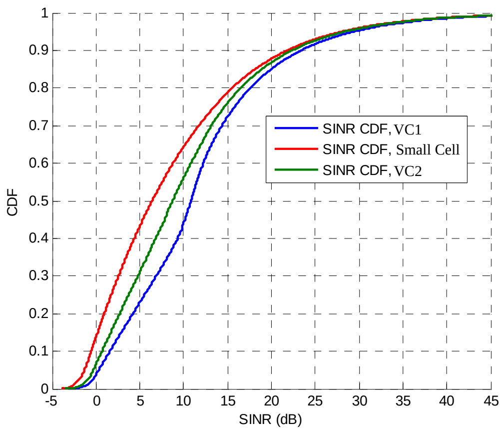


Fig. 5. SINR distribution of different solutions in terms of *CDF*

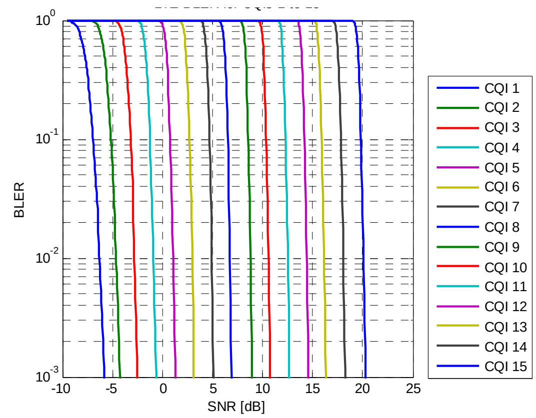
set of Additive White Gaussian Noise (AWGN) link level performance curves are generated in order to assess the BLER of the received Transport Blocks (TBs).

Figure 6 shows the single input single output (SISO) BLER curves for AWGN. A method employed to achieve a TB effective SINR γ_{eff} is the Exponential Effective Signal to Interference and Noise Ratio Mapping (EESM), which can be used to determine the BLER obtained from AWGN link-level simulations [12]. The SINR-to-CQI mapping is understood by using the 10^{-1} points on the BLER curves and taking the corresponding SNR values, as shown in Figure 7. The attained CQIs are later floored to obtain the integer CQI values that are reported back to the eNodeB.

In Figure 8, the CQI is mapped with respect to the remote antenna configuration and the CQI distribution for the Small Cell, VC1, VC2 and VC3 scenarios is demonstrated. VC1 has the best CQI distribution in the central coverage area, which is expected since there is no inter-antenna interference. The Small Cell system has the worst CQI distribution, since no inter-antenna interference mitigation techniques are employed.

C. Shannon Capacity

Capacity theorem is used to determine the total information that can be transmitted over the communication channel. According to the Shannon theorem, the maximum rate of



FIgt.6. BLER Curves obtained from SISO AWGN simulations for all 15 CQI values.

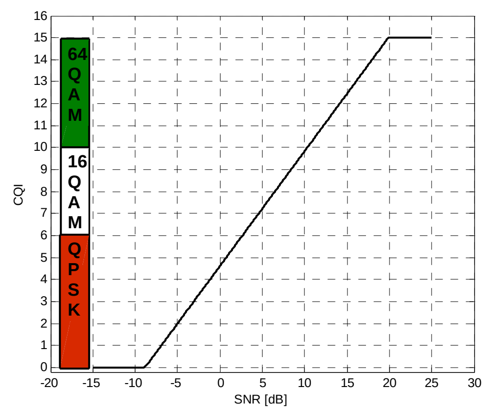


Fig. 7. SINR-to-CQI mapping.

information C for a given communication system is known as channel capacity in bit per second (*bps*) and stated as:

$$C = B\log_2(1+SINR) \tag{5}$$

where B is the bandwidth of channel. The spectral efficiency is defined by:

$$Spectral\ Efficiency = C/B = \log_2(1+SINR) \tag{6}$$

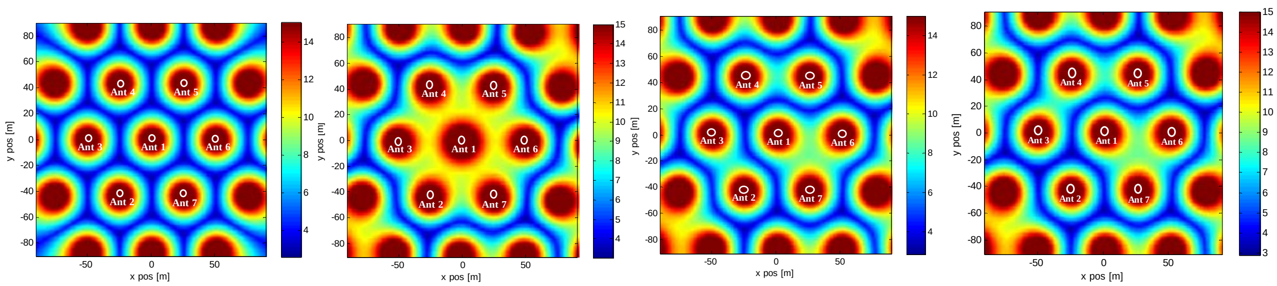


Fig. 8. CQI coverage of 7 central antennas- Small Cells (left), VC1 (middle-left), VC2 (middle-right), VC3 (right)

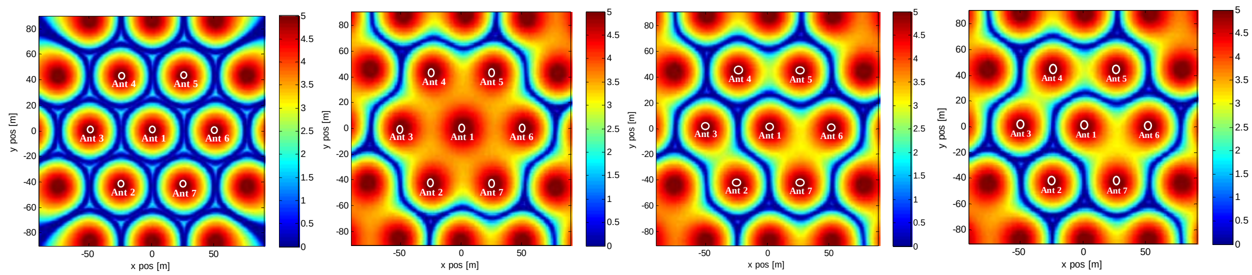


Fig. 9. Virtual Cell vs. Small Cell Spectral Efficiency- Small Cells (left), VC1 (middle-left), VC2 (middle-right), VC3 (right)

Figure 9 displays the spectral efficiency of Small Cell, VC1, VC2 and VC3 scenarios. The simulation results show that over the central coverage area, the VC1 configuration is more spectrally efficient than VC2, VC3 or the Small Cell configuration.

Although beneficial in terms of spectral efficiency, VC1 and VC2 may not achieve as high a throughput per user as Small Cells or VC3 due to the low effective bandwidth per antenna. We design two user profiles to highlight the user throughput with effective bandwidth per user. Note that the useable capacity is defined as the available capacity per cell.

1) Single User Simulation

Figure 10 shows the first scenario when UE1 move from Antenna 7 to Antenna 4.

The results for VC1, VC2, VC3 and Small Cell are shown in TABLE II. Results show that the average SINR for VC1 is around 4 *dB* better than Small Cell and 1.5 *dB* better than VC2 and VC3. Most CQI values used in VC1 were anywhere from 10 to 15 due to better SINR values, which results in a better modulation format. UE1 uses 64-QAM only 45.71% of the time in the Small Cell scenario and 54.81% in the VC2 scenario. However, in the VC1 deployment, 64-QAM is used 62.85%, which shows optimized average simulation useable capacity and average cell spectral efficiency for VC1. In terms of simulation system capacity, Small Cell outperforms VC1 and VC2 by using more eNodeBs. The Small Cell has the same capacity as VC3 in the hot spot.

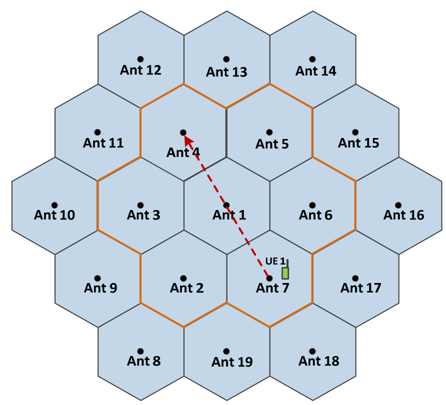


Fig. 10. Structure of Single User Simulation

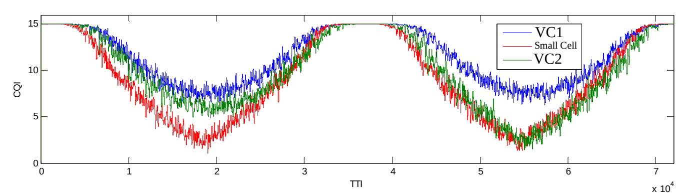


Fig. 11. CQI report is sent by UE1in single user simulation

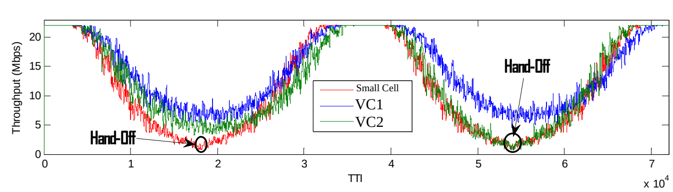


Fig. 12. UE1 throughput in single user simulation

TABLE II. SIMULATION RESULTS OF SCENARIO 1

		VC1 (1 eNB)	VC2 (3 eNBs)	VC 3 (3 eNBs)	Small cell (7 eNBs)
SINR_Ave		13.421	11.915	12.001	9.512
Useable_Capacity_Ave (Mbps)		14.4889	13.001	13.204	10.8494
System_Capacity_Ave (Mbps)		14.4889	26.002	26.408	32.5482
Spectral_Efficiency_Ave (Mbps/Hz)		3.8501	3.6910	3.7006	3.3940
Modulation percentage	QPSK	2.03%	20.65%	19.67%	42.25%
	16-QAM	35.12%	24.54%	25.32%	12.04%
	64-QAM	62.85%	54.81%	55.01%	45.71%

1) Multi-User Simulation

In this scenario, the users are uniformly distributed inside a central area containing seven cells (Antenna 1, 2,…, 7).

Four different user load densities are considered (35, 70, 140, 280), which are uniformly distributed throughout the area. Figure 13 shows the high load density when 280 users are uniformly distributed inside 7 central antennas area.

The results of VC1, VC2, VC3 and Small Cell are shown in TABLE III, IV and V, respectively. The better SINR values in VC1 translate into higher CQIs (between 10 to 15) resulting in a higher modulation format percentage at every load density. Modulation format percentages are shown in TABLE III. Under the high load conditions of 280 users, only 16.7% of Small Cell users are using 64-QAM samples; 27.85% of VC2; yet 56.78% of users in VC1 are using 64-QAM. VC3 is similar in performance to VC2 because the users were assumed to be uniformly distributed in the geographic area.

TABLE IV demonstrates the system performance for VC1, VC2, VC3 and Small Cell using two different schedulers: 1) proportionally fair and 2) Max-Min. In terms of useable capacity and spectral efficiency, the results show that VC1 performs much better than Small Cell and VC2. Because of the larger number of eNodeBs used in the coverage area, the Small Cell system (7 eNodeBs) has a higher overall system capacity than VC1 (1 eNodeB), VC2 (3 eNodeBs) and VC3 (3 eNodeBs).

TABLE V shows the results of the key performance indicators for the different scenarios. The average throughput per user was included as this is a good indicator of customer satisfaction. For a given coverage area, (M:1) is defined as "M antennas are supported by one eNodeB". This is commonly referred to as the simulcast ratio per eNodeB. As a result, VC2 can be seen as utilizing three configurations: (3:1), (2:1) and (2:1). The SINR degrades as we reduce M because of the increased inter-cell interference. The (7:1) configuration outperforms the other configurations in terms of useable capacity and spectral efficiency due to the higher SINR value. The (1:1) configuration for the Small Cell and VC3 antenna 2 outperforms the other configurations in terms of average throughput per user because of a dedicated eNodeB per cell, which results in a larger effective bandwidth per user. The (1:1) configuration supports the lowest number of users per eNodeB in comparison with the other (M:1) configurations.

The results indicate that a Virtual Cell that dynamically alters the simulcast ratio has the ability to achieve throughput performance of a Small Cell at a Hot Spot while achieving the highest spectral efficiency throughout the coverage area. A Virtual Cell in a distributed network architecture is the most cost effective solution as it routes the capacity on demand. Centralizing the base station resources with a distributed network has the added benefit of capacity scalability and centralizing the backhaul infrastructure.

A Small Cell deployment with interference mitigation techniques such as a Self Optimizing Network (SON) would be required in order to improve the spectral efficiency and reduce the hand-offs. However, this would come at the expense of reduced capacity as the resource blocks available per Small Cell would be restricted.

V. CONCLUSION

The performance analysis for an in-building Virtual Cell distributed architecture and a Small Cell architecture was undertaken. Three different scenarios were investigated: 1) (7:1) simulcast ratio VC1 system driven by 1 eNodeB; 2) multiple simulcast ratio VC2 and VC3 systems driven by 3 eNodeBs; and 3) 7 eNodeB Small Cell system. The results indicate that the inter-cell interference from Small Cells have a significant impact on the user performance. Without any coordination between Small Cells, the signal-to-interference plus noise-ratio (SINR) over the geographic area is significantly poorer. This results in the inability for the users to operate at the highest spectral efficiency available from LTE. The increased hand-offs from a poor SINR profile will increase the burden on the network and negatively impact the user experience.

Small Cells provide increased capacity to a given geographic area, whereas a traditional DAS architecture has been viewed as a coverage solution. However, a Virtual Cell distributed network that has the ability to provide capacity on demand by altering the simulcast ratio will, ultimately, provide the most optimal solution. A Virtual Cell distributed network provides the throughput demands at peak loads and maximizes the user experience throughout the entire coverage area. This investigation demonstrates that the throughput data rate of a Virtual Cell distributed network is the same as that of a Small Cell at a Hot Spot yet at a fraction of the required number of eNodeBs. The Virtual Cell distributed network architecture provides the best spectral efficiency and subsequently the highest useable capacity.

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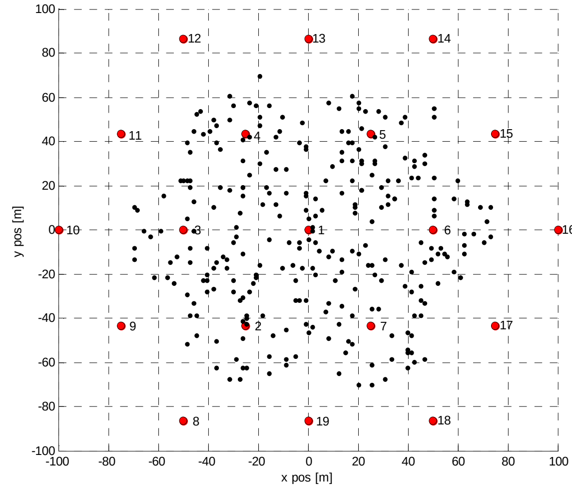

Fig. 13. Structure of scenario 2

TABLE III. MODULATION PERCENTAGE

%	Load (#Active users)	VC 1 (1 eNB)	VC 2 (3 eNBs)	VC 3 (3 eNBs)	Small Cell (7 eNBs)
QPSK	**35**	17.14	40	37.76	67.71
	70	2.86	28.58	27.35	58.58
	140	5.72	27.15	26.14	54.01
	280	7.87	29.3	28.77	50.72
16-QAM	**35**	31.42	40.00	41.48	22.85
	70	40.00	54.28	55	32.85
	140	39.28	47.85	48.65	30.71
	280	35.35	42.85	43.23	32.50
64-QAM	**35**	51.44	20.00	20.76	9.44
	70	57.14	17.14	17.65	8.57
	140	55.00	25.00	25.21	15.28
	280	56.78	27.85	28	16.78

TABLE IV. SIMULATION RESULTS OF SCENARIO 2

	Load (#Active users)	VC 1 (1 eNB)		VC 2 (3 eNBs)		VC 3 (3 eNBs)		Small Cell (7 eNBs)	
		PF*	MM**	PF	MM	PF	MM	PF	MM
SINR Ave	35	8.62		5.32		5.44		3.00	
	70	8.83		6.43		6.49		4.02	
	140	8.75		6.32		6.36		4.31	
	280	9.21		6.57		6.59		4.93	
Useable Capacity (Mbps)	35	16.78	14.16	12.60	9.19	12.84	9.40	10.35	9.96
	70	16.70	14.81	13.75	11.33	14.04	11.89	11.15	8.18
	140	16.87	14.47	14.51	11.53	14.65	11.70	11.80	8.49
	280	17.60	14.73	14.71	11.51	14.77	11.66	12.54	8.82
System Capacity (Mbps)	35	16.78	14.16	37.80	27.58	38.54	28.21	72.47	48.73
	70	16.70	14.81	41.27	34.00	42.13	35.67	78.07	57.27
	140	16.87	14.47	43.55	34.59	43.95	35.12	82.61	59.49
	280	17.60	14.73	44.15	34.55	44.33	34.98	87.78	61.80
Spectral Efficiency eNodeB (Mbps/Hz)	35	3.26		2.66		2.68		2.00	
	70	3.29		2.89		2.90		2.32	
	140	3.28		2.87		2.88		2.40	
	280	3.35		2.92		2.92		2.56	

TABLE V. SIMULATION RESULTS OF SCENARIO 2

	Load (#Active users)	VC 1 7:1		VC 2 3:1		VC 2 2:1		VC 3 1:1		Small Cell 1:1	
		PF	MM	PF	MM	PF	MM	PF	MM	PF	MM
SINR Ave	35	8.62		6.10		5.32		2.96		3.00	
	70	8.83		6.62		6.55		3.98		4.02	
	140	8.75		7.48		5.51		4.28		4.31	
	280	9.21		7.01		6.88		4.92		4.93	
Useable Capacity (Mbps)	35	16.78	14.16	13.94	10.74	12.74	8.882	10.08	9.85	10.35	9.96
	70	16.70	14.81	16.01	12.46	13.11	11.18	11.00	8.01	11.15	8.18
	140	16.87	14.47	15.93	13.63	15.16	11.23	11.78	8.36	11.80	8.49
	280	17.60	14.73	18.80	12.91	13.93	10.91	12.53	8.81	12.54	8.82
Ave Throughput Per user (Mbps)	35	0.47	0.40	0.92	0.71	1.27	0.88	2.00	1.97	2.07	1.99
	70	0.23	0.21	0.53	0.41	0.65	0.55	1.10	0.80	1.11	0.81
	140	0.12	0.10	0.26	0.22	0.37	0.28	0.58	0.41	0.59	0.42
	280	0.06	0.05	0.15	0.10	0.17	0.13	0.31	0.22	0.31	0.22
Spectral Efficiency eNodeB (Mbps/Hz)	35	3.26		2.82		2.66		1.98		2.00	
	70	3.29		2.93		2.91		2.31		2.32	
	140	3.28		3.08		2.70		2.40		2.40	
	280	3.35		3.00		2.97		2.56		2.56	

*Proportional Fair Scheduler
** Max-Min Scheduler