

Cloud RAN: Enabling NFV in Mobile Networks

Frank Rayal, XONA Partners
and Joe Madden, Mobile Experts

February 2015



MOBILE EXPERTS

List of Figures	5
List of Tables	8
Executive Summary.....	9
Synopsis of C-RAN Developments in the Past Year (2014)	13
Drivers of Cloud RAN Architecture	15
Evolution of the Base Station Architecture.....	17
Cloud RAN: Definition and Description.....	20
Benefit of Cloud RAN Architecture	24
Reduction of Site Rental Expenses.....	24
Savings in Operation and Maintenance Costs	25
Savings in Power Consumption.....	26
Utilization of Baseband Resources.....	28
Network Capacity Benefits – Coordinated Multipoint.....	30
Challenges to Cloud RAN Implementation	38
Virtualization of Baseband Processing.....	38
Fronthaul Performance Requirements	38
Option.....	39
Solutions to C-RAN Challenges	41
Architecture modifications	41
CPRI compression.....	46
IP fronthaul interfaces	46

Cloud RAN Fronthaul Topologies	48
Optical Technologies.....	49
Cloud RAN in the Balance	50
Fiber Availability.....	50
Deployment Considerations	52
Wireless Fronthaul in Cloud RAN.....	53
Cloud RAN Deployment Scenarios	55
The Early Adopters.....	55
The Pragmatic Followers.....	56
Cloud-RAN in Special Deployments	58
Cloud-RAN for Network Sharing	58
Comparison and Contrast with DAS and Compact Base Stations.....	60
C-RAN versus Distributed Antenna Systems.....	60
C-RAN versus Small Cells.....	63
Cost-Benefit Analysis	70
Case Study 1: North American operator with leased fiber	72
Case Study 2: Asian operator with owned dark fiber	75
Case Study 3: Cloud RAN in HetNet Deployment	79
Case Study 4: Cloud RAN versus DAS Deployment	82
Market Forecast.....	85
Macrocell Cloud and Centralized RAN Deployments.....	86
HetNet Cloud RAN Deployments	90

Acronyms	92
Appendix 1	95
Appendix 2	98

List of Figures

Figure 1 Forecasted RRH sectors deployed into a Cloud RAN configuration, 2014-2019. 9

Figure 2 Cloud RAN ecosystem.12

Figure 3 Baseband virtualization decouples software from hardware by introducing a hypervisor on a platform of general purpose processors..... 16

Figure 4 Legacy base station architecture.....17

Figure 5 Split base station architecture. 18

Figure 6 Compact base station architecture (small cell). 19

Figure 7 Simplified Cloud RAN architecture. 19

Figure 8 Radio access network centralization options..... 20

Figure 9 Cloud RAN architecture.....21

Figure 10 Distributed network architecture vs. Cloud RAN..... 23

Figure 11 Annual site rental expenses. 25

Figure 12 Cumulative distribution function (CDF) for the distribution of traffic in an operator network. In most networks ~15-20% of sites carry 50% of traffic..... 29

Figure 13 Coordinated multipoint in LTE networks..... 32

Figure 14 Partial benefits of CoMP can be realized in boundary region between sectors of a cell in high-latency distributed architecture. Cloud RAN CoMP benefits occur around the perimeter of a cell in addition to between sectors α , β , and γ 33

Figure 15 Scenario 1: homogeneous network with intra-site CoMP (Based on 3GPP TR 36.819)..... 34

Figure 16 Scenario 2: homogeneous network with high Tx power RRHs (Based on 3GPP TR 36.819).. 34

Figure 17 Scenario 3: network with low power RRHs within the macrocell coverage (Based on 3GPP TR 36.819)..... 34

Figure 18 CoMP and eICIC can be combined to optimize the capacity benefit against the cost of the transport network. 37

Figure 19 CPRI Rate per channel for different access technologies.	40
Figure 20 The LTE protocol stack.	42
Figure 21 Alternative RAN splits of base station function to reduce fronthaul line rate requirements in Cloud RAN deployments.	43
Figure 22 PHY-layer functional splits. The green blocks are user-level functions; blue blocks are cell-level functions.	44
Figure 23 Cloud RAN in a star/tree topology.	48
Figure 24 Cloud RAN in a ring topology.	49
Figure 25 Base Station Sites within the City of Toronto Limit: 599 sites covering 750 sq. km.	53
Figure 26 Cloud RAN deployment scenarios by Korean operators.	56
Figure 27 Active distributed antenna system.	60
Figure 28 Backhaul traffic requirements for LTE small cells in different profiles. Source: NGMN.	65
Figure 29 Path imbalance in small cell deployments ⁴¹	66
Figure 30 Dual connectivity in HetNets allow mobile to connect to two base stations.	66
Figure 31 Downlink dual connectivity options explored in LTE Release 12 ⁴¹	67
Figure 32 Dual connectivity options for data and control planes selected for further standardization in LTE Release 12 ⁴¹	68
Figure 33 Base case 8-Year TCO comparison between Cloud RAN and distributed architecture for North American operator without owned fiber assets and with dark fiber available on site. This case applies to only 43% of sites leading to failure of the Cloud RAN business case.	74
Figure 34 Normalized CAPEX comparison between Cloud RAN and distributed architecture for North American operator without owned fiber assets and with dark fiber available on site.	75
Figure 35 Normalized OPEX comparison between Cloud RAN and distributed architecture for North American operator without owned fiber assets and with dark fiber available on site.	75
Figure 36 8-Year TCO comparison between Cloud RAN and distributed architecture for Asian operator with owned fiber assets. This base case scenario shows 27% savings.	77

Figure 37 Normalized CAPEX comparison between Cloud RAN and distributed architecture for Asian operator with owned fiber assets. This base case scenario shows 28% CAPEX savings.	77
Figure 38 Normalized OPEX comparison between Cloud RAN and distributed architecture for Asian operator with owned fiber assets. This base case scenario shows 26% OPEX savings.	78
Figure 39 Cost of capacity (\$/Mbps) comparison between Cloud RAN and distributed architecture for Asian operator with owned fiber assets. This base case scenario shows 36% savings.	78
Figure 40 Relative cost for a macro cell and 6 remote cells.	81
Figure 41 Cost of capacity versus remote cell utilization.	82
Figure 42 TCO per sector in DAS and Cloud RAN architecture.	84
Figure 43 Annual high-power sectors in centralized base station mode.	86
Figure 44 Cumulative installed base of Centralized RAN high power RRH sectors.	87
Figure 45 Annual high power RRH sectors deployed in Centralized RAN, TDD vs FDD.	87
Figure 46 Annual high-power sectors shipped in Cloud RAN configuration.	88
Figure 47 Cumulative installed base of Cloud RAN base station sectors.	89
Figure 48 Annual Cloud RAN sectors deployed, TDD vs FDD.	89
Figure 49 Annual low power RRH shipments, Centralized RAN configuration (including indoor and outdoor).	90
Figure 50 Annual outdoor low power RRH shipments, Cloud RAN configuration.	91
Figure 51 Annual low power RRH shipments for Cloud RAN, TDD vs FDD.	91
Figure 52 Cumulative distribution function for 8-year TCO improvement in Cloud RAN over distributed architecture.	96
Figure 53 Contribution to variance of 8-Year Cloud RAN TCO for North American operator without owned fiber.	97
Figure 54 8-year TCO improvement of Cloud RAN over distributed architecture for Asian operator with owned fiber assets.	99
Figure 55 Sensitivity of 8-year Cloud RAN TCO in case of Asian operator with own fiber assets.	100

List of Tables

Table 1 Comparative overview between distributed and Cloud RAN architectures. 23

Table 2 High-level summary of Cloud RAN benefits and challenges..... 24

Table 3 Select FD-LTE CoMP gain for homogeneous scenarios 1 and 2 (source: 3GPP²⁰). 35

Table 4 Select FD-LTE CoMP gain for heterogeneous network implementing eICIC (source: 3GPP²⁰). 35

Table 5 CPRI Line bit rates (Gbps) for a single LTE channel. 39

Table 6 CPRI Line bit rate options..... 39

Table 7 Data rate for different baseband functional splits between the DUC and RRH²⁵. 44

Table 8 Advantages and disadvantages of different physical layer functional splits in C-RAN²⁵. 44

Table 9 Performance of C-RAN architectural splits against key features and requirements. 45

Table 10 Site distance versus number of BBU centers in a North American city..... 52

Table 11 Fronthaul transport options. 54

Table 12 Comparison between small cell backhaul and Cloud RAN fronthaul requirements. 64

Table 13 Comparison on key features between small cells, DAS and Cloud RAN 68

Table 14 Description of key parameters in a Cloud RAN cost model. 70

Table 15 Cell-average gain for coordinated multipoint 72

Table 16 Base case cell site cost structure for North American operator without own fiber assets 72

Table 17 Base case cell site cost structure for Asian operator with own fiber assets..... 76

Table 18 Distributed antenna system capital and operation costs (per sector)..... 82

Table 19 Base station capital and operation costs (per sector, venue deployment)..... 83

Table 20 Per sector 8-year TCO comparison between DAS and Cloud RAN..... 83

Table 21 Statistical variables assumptions in North American operator TCO calculations 95

Table 22 Statistical variables assumptions in Asian operator TCO calculations 98