Institute for Infocomm Research

A*STAR

Heterogeneous Networks: An Evolution Path to 5G for Smart Nation

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Evolving ICM Landscape

Exponential network data traffic growth

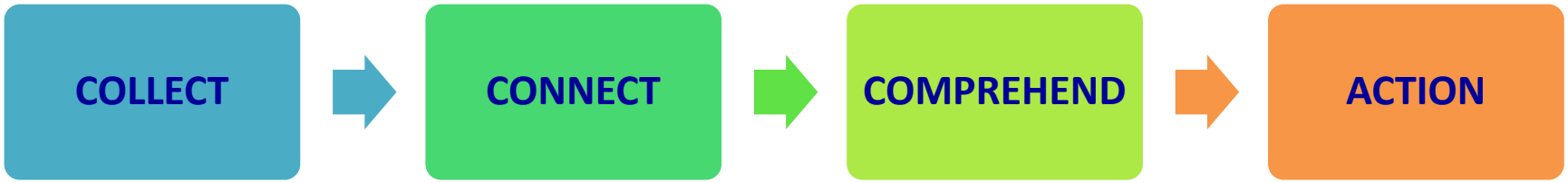
Widespread use of mobile consumer device and services

Digitisation of information and media content

CAPEX/OPEX reduction for sustainable ICT

“Smart” Everywhere

- Smart home
- Smart grid
- Intelligent transportation
- Smart city
- Smart nation



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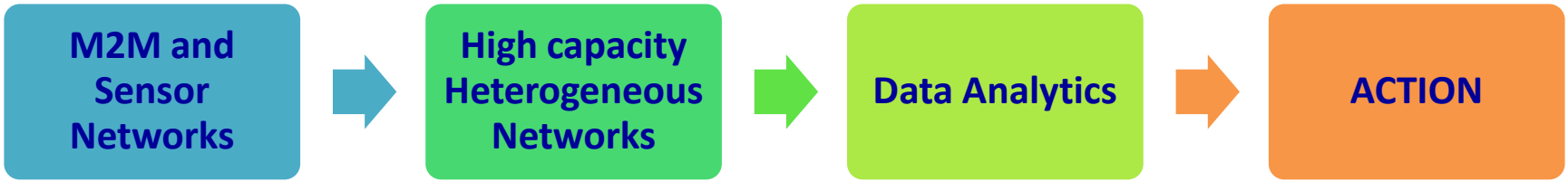

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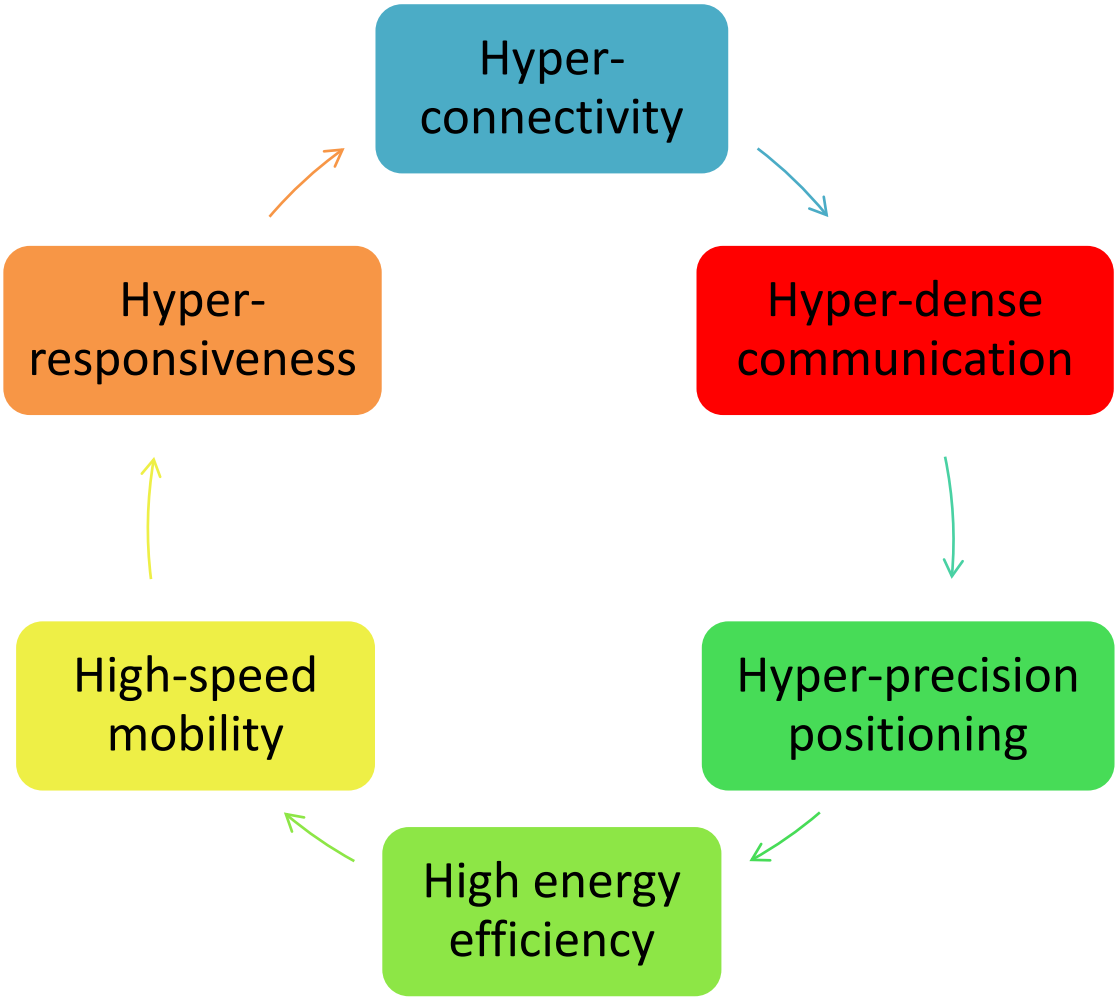
5G Network:

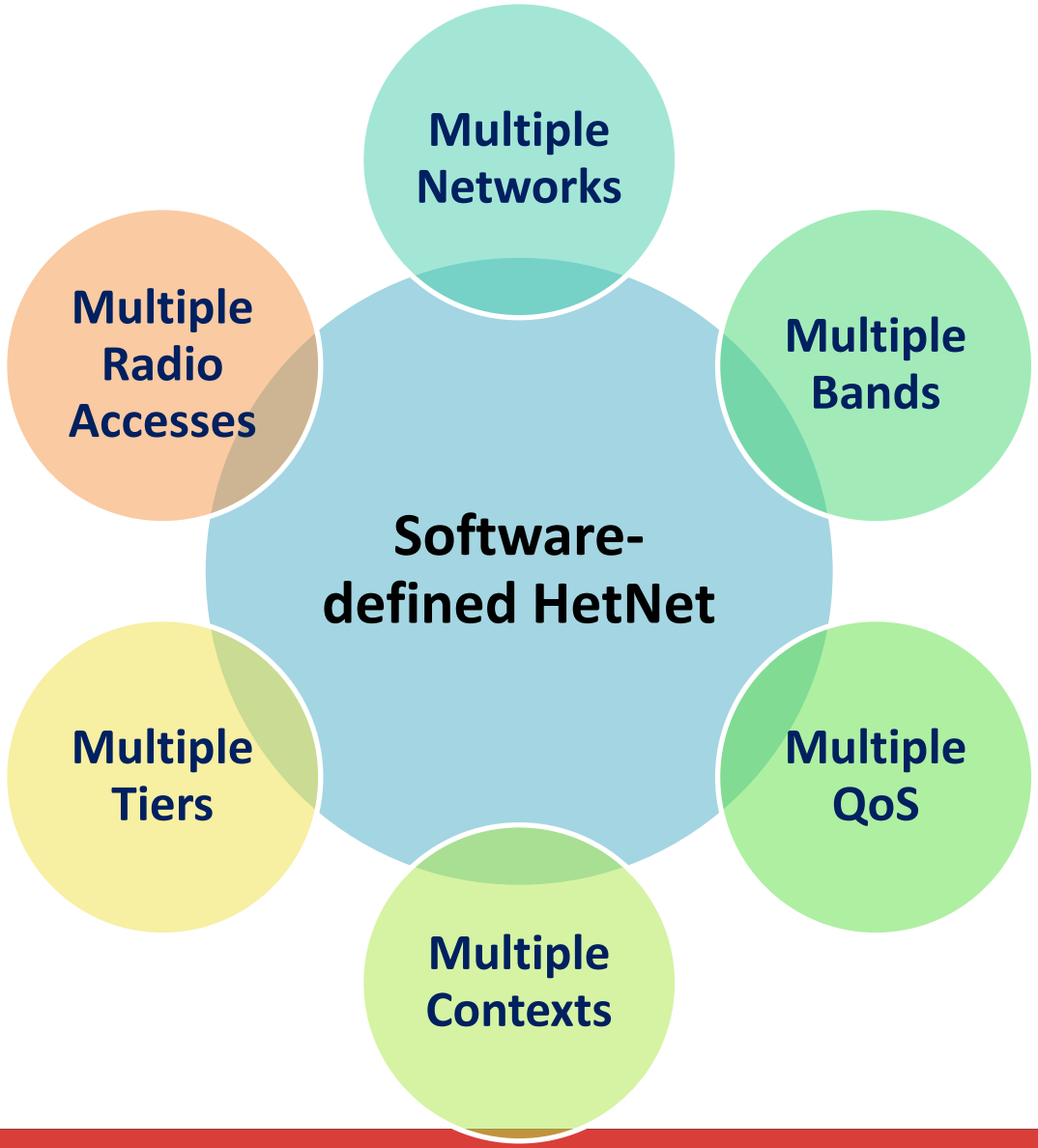
Energy- and Spectrum-Efficient Connectivity for

Everyone
Everything
Everywhere
All the Time

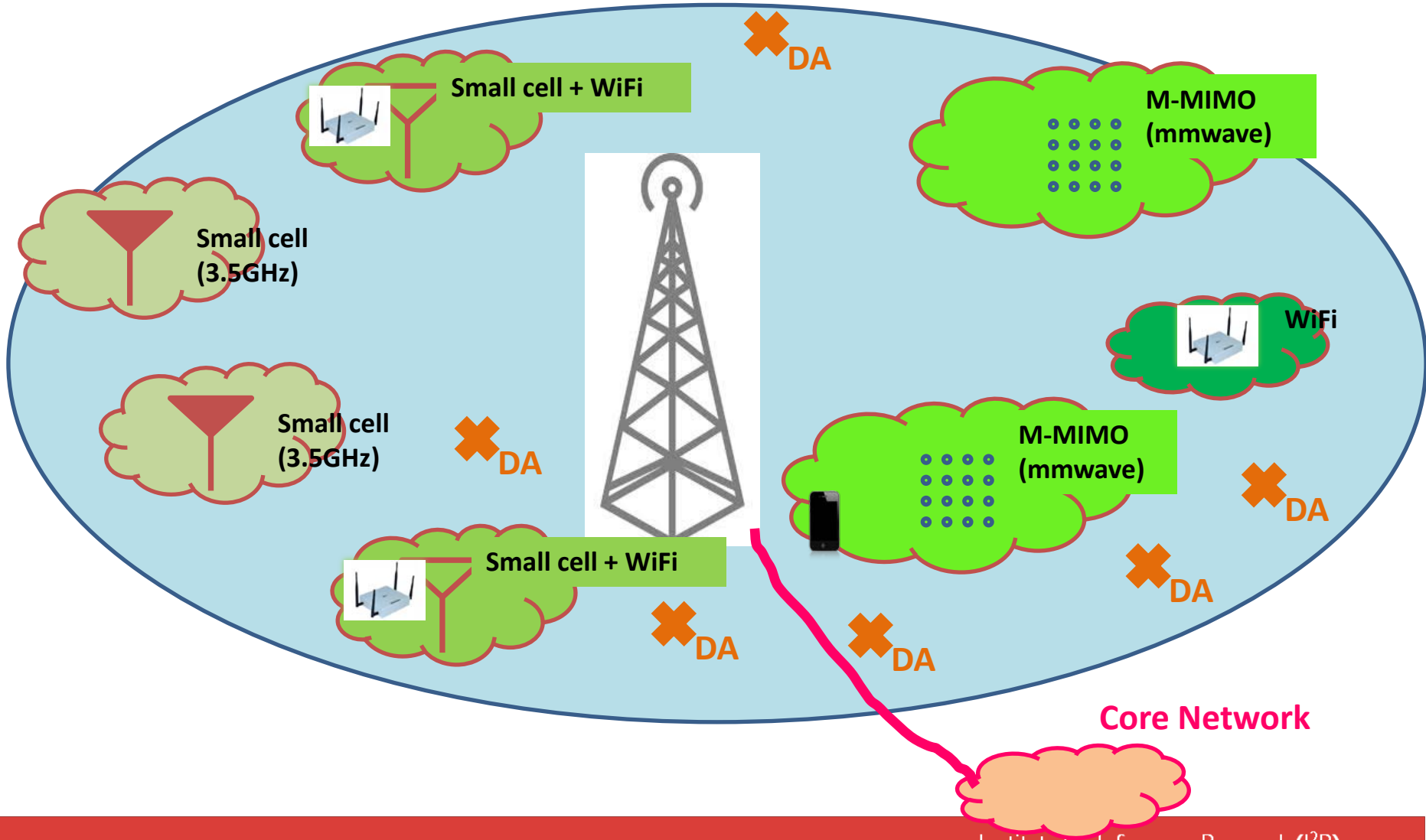
Characteristics of 5G: Service Requirement



Characteristics of 5G: Heterogeneity



HetNet: Intelligent Integration of Multi-RAT, Multi-Layer, Multi-Network , Over Multiple Spectrums

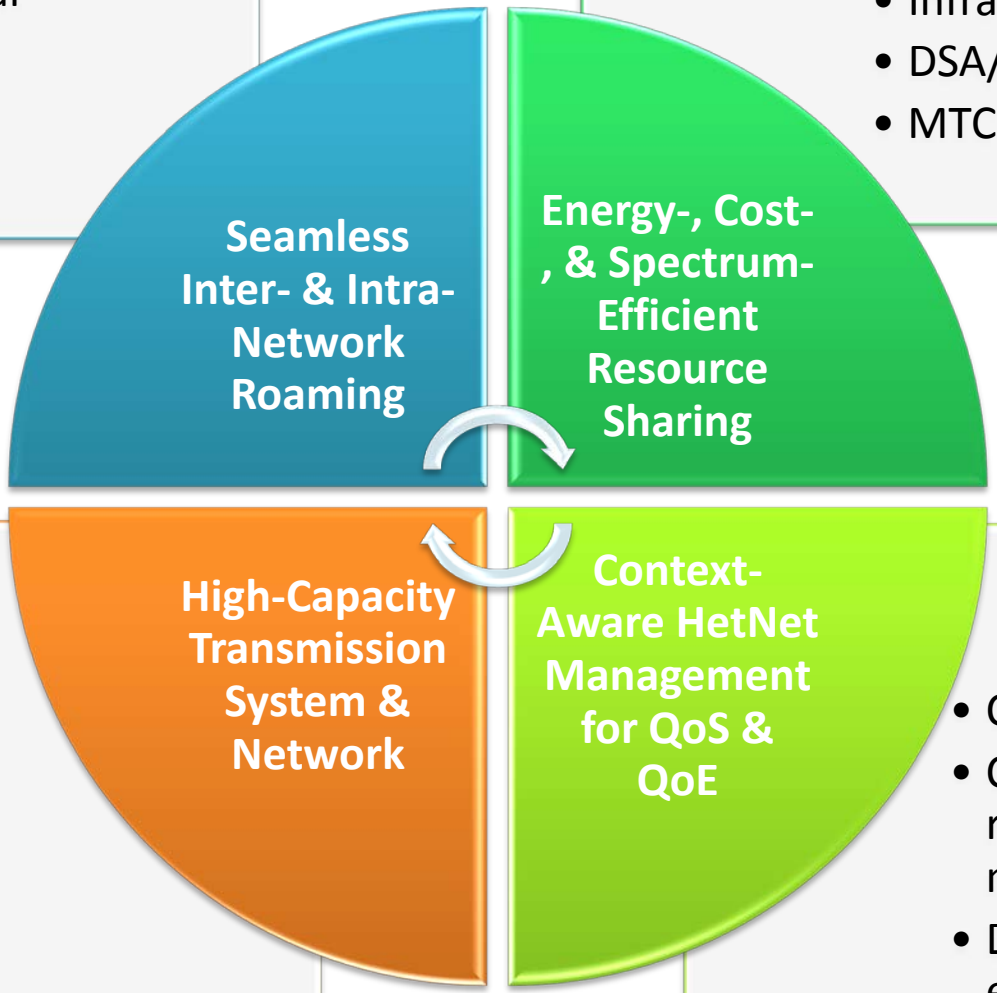


Our Areas of Focus

Context-Aware, Fast-Adapting, Spectrum and Energy-Efficient HetNet

- Multi-tier cellular
- WiFi

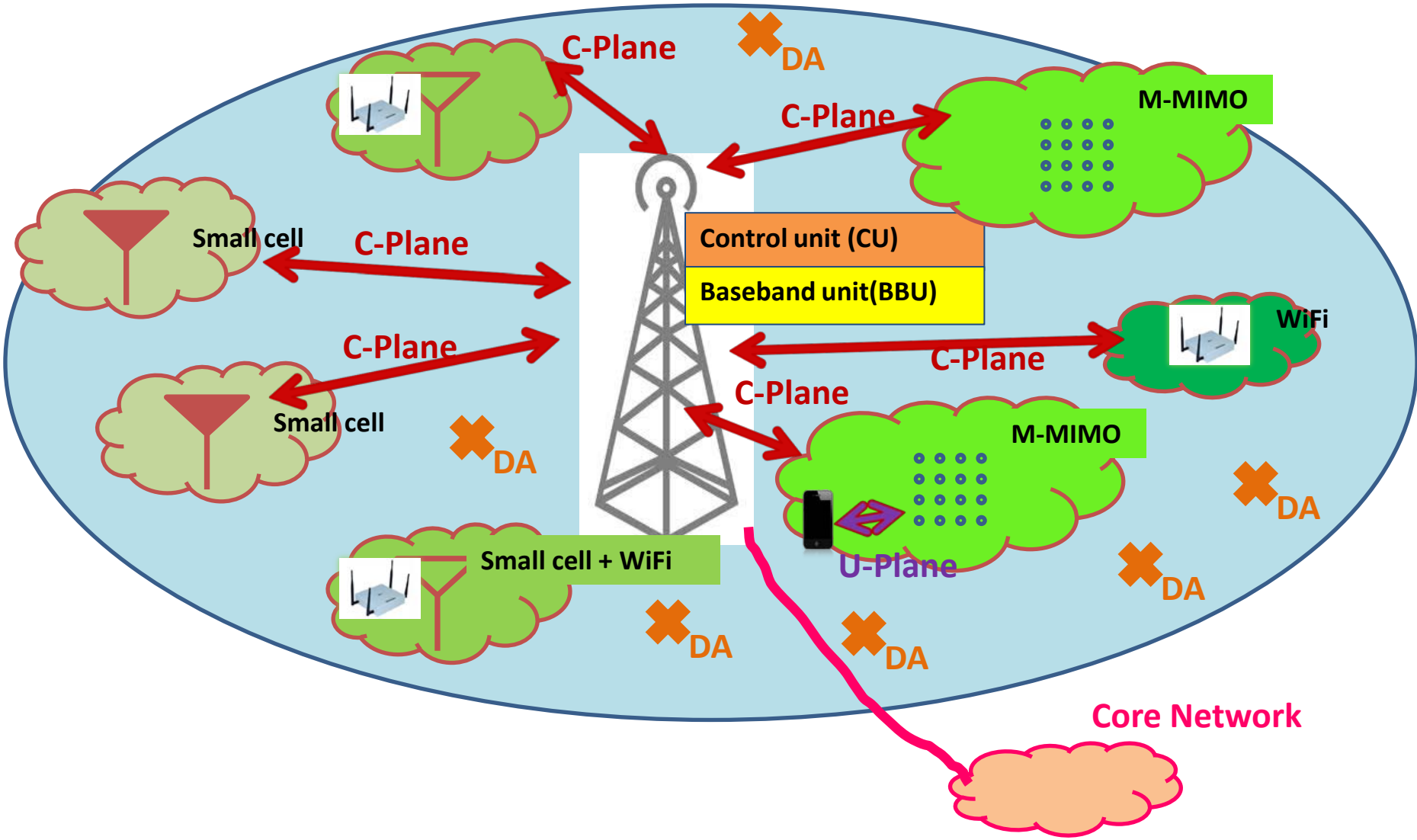
- Infrastructure sharing
- DSA/OSA/LAA
- MTC integration



- C-RAN/L-DAS
- Large MIMO
- Seamless Fronthaul-RAN

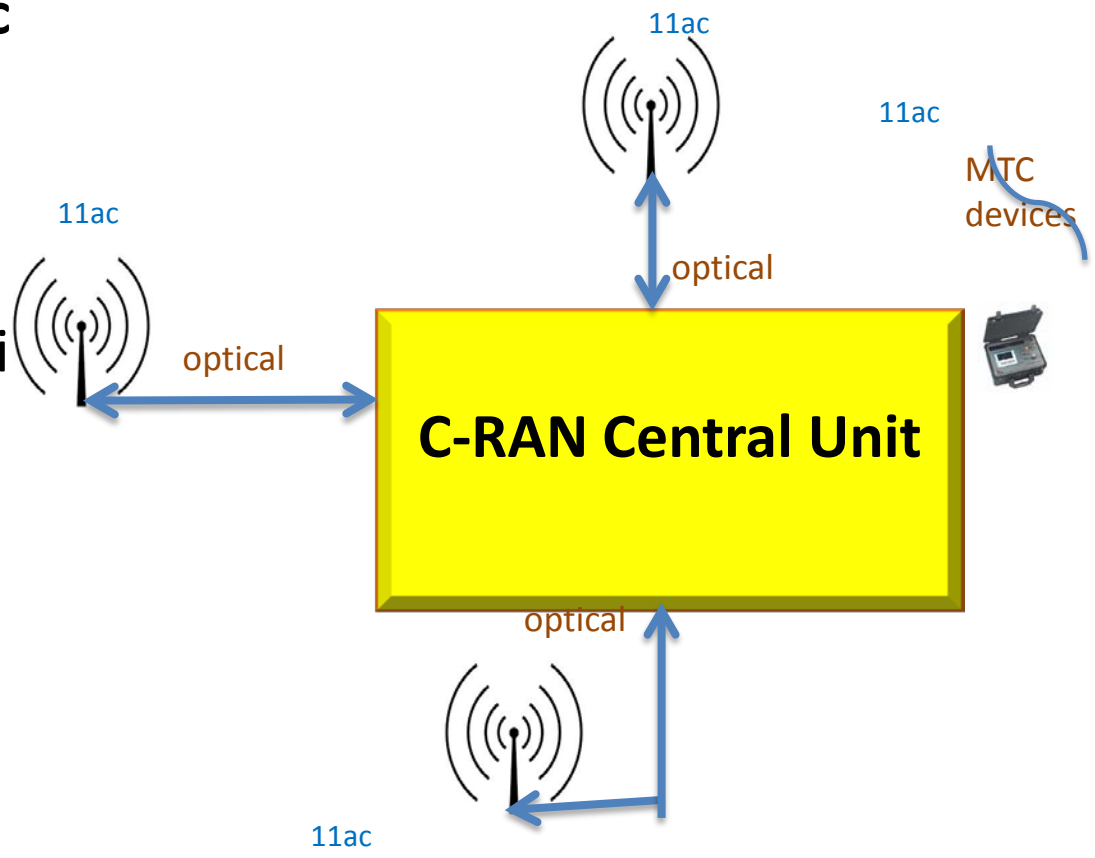
- Context derivation
- Context-aware resource & network management
- Distributed storage & edge computing

Software Defined Radio Access Network (SDRAN)



A Lab Test Bed

- Integration of optical front-haul and with **11ac** wireless transmission system
- 8 Antennas at Access Poi
  - Active Antenna System
- Unified architecture for MTC integration
- demo



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Thank you!

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Recent Publications(1)

1. X. Kang, Y. K. Chia, H. F. Chong, and Sumei Sun, *"Ergodic Sum-Rate Maximization for Fading Cognitive Multiple Access Channels without Successive Interference Cancellation,"* IEEE Trans Vehicular Technology, *accepted*
2. J. Joung, C. K. Ho, K. Adachi, and Sumei Sun, *"A Survey on Power-Amplifier-Centric Techniques for Spectrum and Energy Efficient Wireless Communications,"* IEEE Communications Surveys & Tutorials, *accepted*
3. X. Kang, Y. K. Chia, and Sumei Sun, *"Mobile Data Offloading through A Third-Party WiFi Access Point: An Operators Perspective,"* IEEE Trans Wireless Communications, *accepted*
4. X. Kang, Y. K. Chia, C. K. Ho, and Sumei Sun, *"Cost Minimization for Fading Channels with Energy Harvesting and Conventional Energy,"* IEEE Trans Wireless Communications, *accepted*
5. J. Leithon, Sumei Sun, and T. J. Lim, *"Energy management strategies for base stations in a smart grid environment,"* Transactions on Emerging Telecommunications Technologies, 5 AUG 2014, DOI: 10.1002/ett.2861
6. J. Joung, and Sumei Sun, *"EMA: Energy-Efficiency-Aware Multiple Access,"* IEEE Communications Letters, *accepted*
7. M. Li, Z. Chen, P. H. Tan, Sumei Sun, and Y.-P. Tan, *"QoE-aware video streaming for SVC over multiuser MIMO-OFDM systems,"* Journal of Visual Communication and Image Representation, *accepted*
8. J. Joung, Y. K. Chia, and Sumei Sun, *"Energy-Efficient, Large-scale Distributed-Antenna System (L-DAS) for Multiple Users,"* IEEE Journal of Selected Topics in Signal Processing (JSTSP), accepted
9. C. K. Ho, D. Yuan, and Sumei Sun, "Data Offloading in Load Coupled Networks: A Utility Maximization Framework," IEEE Trans Wireless Communications, accepted
10. Y. K. Chia, Sumei Sun, and R. Zhang, "Energy Cooperation in Cellular Networks with Renewable Powered Base Stations," IEEE Trans Wireless Communications, accepted
11. J. Joung, C. K. Ho, and Sumei Sun, "Spectral Efficiency and Energy Efficiency of OFDM Systems: Impact of Power Amplifiers and Countermeasures," IEEE JSAC, *Special Issue on energy-efficient wireless communications*, vol. 32, iss. 2, pp. 208-220, Feb. 2014.
12. L. Lei, D. Yuan, C. K. Ho, and Sumei Sun, "A Unified Graph Labeling Algorithm for Consecutive-Block Channel Allocation in SC-FDMA," IEEE Trans. Wireless, Vol. 12, Issue 11, pp. 5767 - 5779, Nov. 2013 *(Best Student Journal Paper Award of IEEE Sweden VT-COM-IT Joint Chapter 2014)*
13. J Joung, and Sumei Sun, *"SCF: Sparse Channel-State-Information Feedback using Karhunen-Loeve Transform,", IEEE Globecom 2014Workshop - Massive MIMO: From Theory to Practice*
14. J Joung, C. K. Ho, and Sumei Sun, *"Power Amplifier Switching/Selection (PAS) for Energy Efficient MIMO Systems,", IEEE Globecom 2014 2nd Workshop on Green Broadband Access*
15. Y. K. Chia, C. K. Ho, and Sumei Sun, *"Data Offloading with Renewable Energy Powered Base Station Connected to a Microgrid,", IEEE Globecom 2014*
16. X. Kang, H. F. Chong, Y. K. Chia, and Sumei Sun, *"Sum-Rate Maximization for Spectrum-Sharing Cognitive Multiple Access Channels without Successive Interference Cancellation,",*IEEE Globecom 2014

Recent Publications(2)

17. X. Kang, C. K. Ho, and Sumei Sun, *"Optimal Time Allocation for Dynamic-TDMA-based Wireless Powered Communication Networks,", IEEE Globecom 2014*
18. X. Kang, C. K. Ho, and Sumei Sun, *"Charging and Transmission Time Minimization for Wireless Powered Communication Networks,", IEEE Globecom 2014*
19. B. S. Thian, H. D. Nguen, and Sumei Sun, *"Linear Precoder for Codeword Error Minimization in MIMO Systems with Channel Estimation Errors,", IEEE Globecom 2014*
20. H. D. Nguen, R. Zhang, and Sumei Sun, *"On Design of Improper Signaling for SER Minimization in K-User Interference Channel,", IEEE Globecom 2014*
21. K. Adachi, J. Joung, Sumei Sun, and P. H. Tan, "Adaptive Coordinated Napping (CoNap) for Energy Saving in Wireless networks," IEEE Trans. Wireless Comm, Vol. 12, Issue 11, pp. 5656 - 5667, Nov. 2013
22. J. Joung and Sumei Sun, "Energy Efficient ZF-Based Multiuser MIMO for Distributed Transmitters," IEEE Comm. Letters, Vol. 17, Issue 9, pp. 1766 - 1769, September 2013
23. C. K. Ho, P. H. Tan, and Sumei Sun, "Energy-efficient relaying over multiple slots with causal CSI," IEEE JSAC, Vol. 31, Issue 8, pp. 1494 - 1505, August 2013
24. K. Adachi, J. Joung, S. Sun, and P. H. Tan, "Energy-efficient coordinated napping (CoNap) for wireless networks," Globecom 2012 Workshop
25. P. H. Tan, C. K. Ho, and S. Sun, "OFDM Modulated Cooperative Multiple Access Channel with Network-Channel Coding," IEEE Trans. Wireless Comms, Vol. 11, Issue. 2, Feb. 2012, pp. 604 - 613
26. C. K. Ho, P. H. Tan, and S. Sun, "Maximum diversity order in cooperative MAC for general modulation schemes," IEEE Commun. Lett., vol. 13, issue 12, pp. 941-943, December 2009.
27. P. H. Tan, C. K. Ho, and S. Sun, "Optimality of separate network-channel coding," in Proc. IEEE ICC, 2011, pp. 1-6.
28. S. Sun, "Wireless network coding for cooperative communications," in Proc. IEEE ICCS, 2010, pp. 166-170.
29. P. H. Tan, C. K. Ho, and S. Sun, "Design of distributed multiple turbo codes for block-fading relay channels," in Proc. IEEE ICC, 2010, pp. 1-5.
30. P. H. Tan, C. K. Ho, and S. Sun, "Cooperative multiple access channels in OFDM systems: Diversity order analysis and code design," in Proc. IEEE ISTC, 2010, pp. 181-185.
31. P. H. Tan, C. K. Ho, and S. Sun, "Joint network-channel code design for block fading cooperative multiple access channel," in Proc. IEEE ITW, 2010, pp. 1-5.
32. K. Adachi and S. Sun, "Powe-efficient dynamic BS muting in clustered cellular system," IEEE PIMRC 2012
33. J. Joung, C. K. Ho, and S. Sun, "Tradeoff of spectral and energy efficiencies: impact of power amplifiers on OFDM systems," IEEE Globecom 2012

Recent Publications(3)

34. Y. K. Chia, S. Sun, and R. Zhang, “Energy cooperation in cellular networks with renewable powered base stations,” IEEE WCNC 2013
35. K. Adachi, K. Takeda, Sumei Sun, and F. Adachi, “Joint Cooperative-Transmit and Receive FDE for Single-Carrier Incremental Relaying,” IEEE Trans Vehicular Technology, Vol 62, Issue 1, pp. 1 - 13, Jan 2013
36. J. Joung, C. K. Ho, and S. Sun, “Green wireless communications: a power amplifier perspective,” Asia Pacific Signal and Information Processing Association (APSIPA) Annual Summit and Conference, Dec 2012
37. J. Joung, C. K. Ho, and S. Sun, “Power amplifier switching (PAS) for energy efficient systems,” IEEE Wireless Comm Letters, Feb. 2013
38. J. Joung, C. K. Ho, and S. Sun, “Power amplifier switching/selection (PAS) for energy efficient MIMO systems”, submitted to Globecom 2014
39. K. Adachi, S. Sun, and C. K. Ho, “Power minimization of cooperative relay transmission with relay’s private information,” IEEE Trans. Wireless Comms, Vol 11, Issue 7, pp. 2520 – 2530, July 2012
40. C. K. Ho, P. H. Tan, and S. Sun, “Energy-efficient relaying over multiple slots with causal CSI,” to appear, IEEE JSAC, special issue on Theories and Methods for Advanced Wireless Relays
41. J. Joung and S. Sun, “Power efficient resource allocation for downlink OFDMA relay cellular networks,”, IEEE Trans. Signal Processing, Vol. 60, No. 5, May 2012, pp. 2447 – 2459
42. K. Adachi, S. Sun, and C. K. Ho, “Power minimization of cooperative relay transmission with relay’s private information,” IEEE VTC 2011 Fall
43. K. Adachi, S. Sun, and J. Joung, “Cooperative relay transmission with relay’s private information,” IEEE VTC 2011 Spring
44. K. Adachi and S. Sun, “Inter-Sector cooperative relaying for network power minimization,” IEEE VTC 2012 Spring
45. C. K. Ho, P. H. Tan, and S. Sun, “Relaying for energy-efficient scheduling with deadline,”, IEEE ICC 2010
46. C. K. Ho, P. H. Tan, and S. Sun, “Relaying over Multiple Slots with Causal CSI: Optimal Power Allocation for Energy Minimization,” IEEE ICC 2012
47. C. K. Ho, P. H. Tan, and S. Sun,, “Relaying with deadline constraint: energy minimization with full channel state information,” IEEE VTC 2012 Spring
48. C. K. Ho, D. Yuan, and S. Sun, “Data Offloading in Load Coupled Networks: Solution Characterization and Convexity Analysis,” ICC 2013
49. K. Adachi and S. Sun, “An Asymmetric TDD Distributed Massive Antenna System,” IEEE ICCC 2013, Invited paper
50. J. Joung, Y. K. Chia, and S. Sun, “Energy efficient multiuser MIMO systems with distributed transmitters ,” IEEE Globecom 2013
51. C. K. Ho, D. Yuan, L. Lei ,and S. Sun, “On Power and Load Coupling in Cellular Networks for Energy Optimization”, to be presented in ICC’14
52. X. Kang, Y. K. Chia, and Sumei Sun, “Mobile Data Ooading through A Third-Party WiFi Access Point: An Operators Perspective," IEEE Globecom 2013
53. J. Leithon, Sumei Sun, and T. J. Lim, “Energy Management Strategies for Base Stations Powered by the Smart Grid," IEEE Globecom 2013