When ICN Meets C-RAN for HetNets: An SDN Approach

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Motivation

- Mobile Internet and explosion of its applications, users are experiencing abundant services from different content providers via different network service providers in heterogeneous network.

- Information centric network (ICN) advocates getting rid of current host-centric network protocol because information dissemination rather than end-to-end communication contributes to majority of today's network traffic.

- Smart traffic transmission.

- CRAN is one of emerging architecture evolutions on wireless side for easier infrastructure deployment and network management

- Integrate ICN protocol with C-RAN architecture to achieve more efficient communication and information management

- SDN flexibility and reconfigurability of dense HetNets; its inherent advantage lies in global uniform control of wired network.

- Integration of ICN, CRAN, and SDN for HetNet to achieve a win-win situation.

Motivation

- Despite tremendous amount of data traffic in network, only a few contents are frequently accessed by users

- Caching most popular contents in RAN or evolved packet core (EPC) can reduce redundant access and duplicated transmission

- ICN decouples information from its location and sources by defining named data objects (NDOs).

- Widespread caching and broadcasting allow users to get information from optimal node based on name and/or location of information.

Contribution

- Integrating ICN protocol into C-RAN architecture can achieve better communication with efficient distribution of information via ubiquitous cache enabled devices.

- Burden of upper layer (e.g., CN) will be significantly reduced when user requests can be responded to immediately by entity (e.g., BBU) that has cached a copy of requested information.

Information-centric SDN with C-RAN
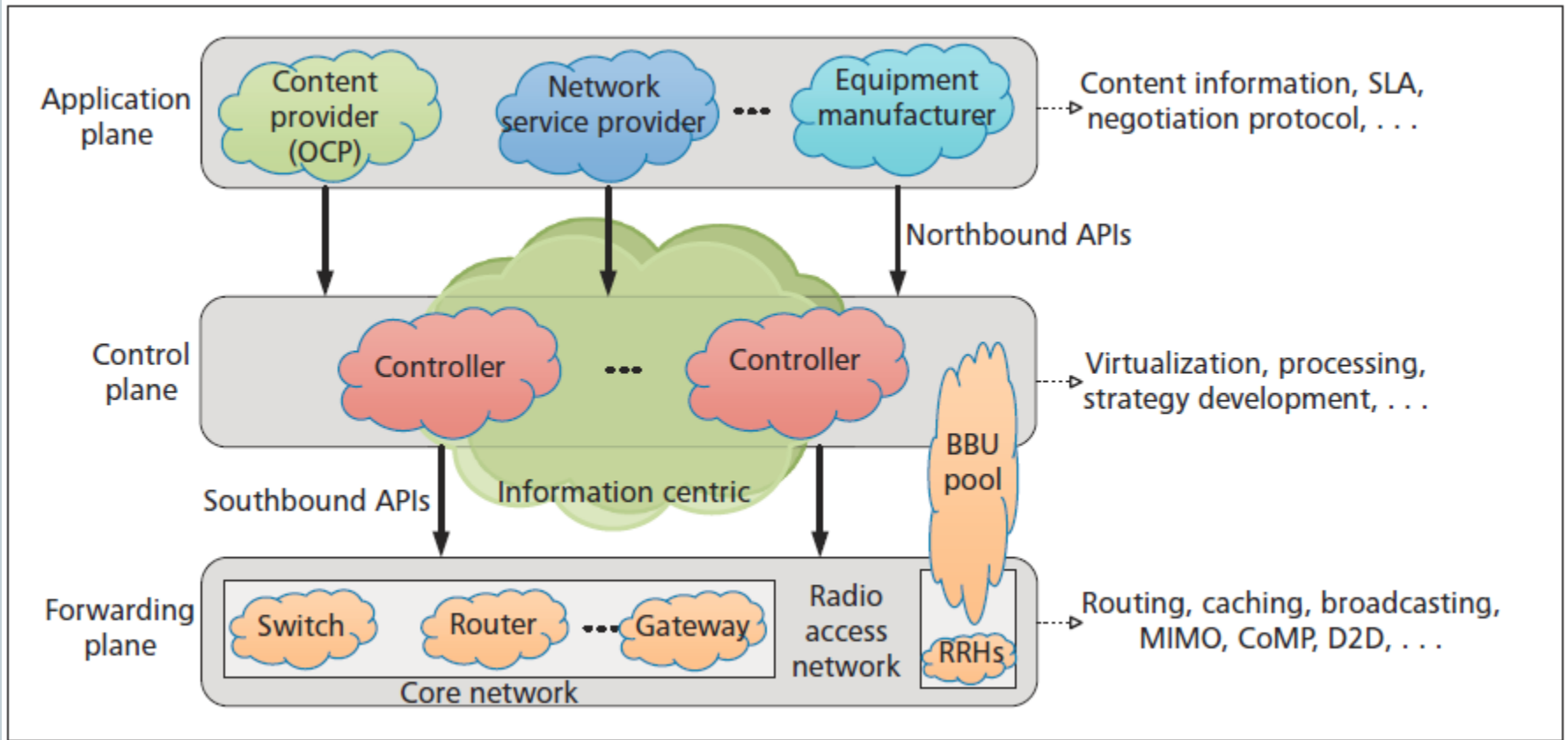
Architecture explained

- Application plane consists of application and service provided by following three entities: content provider (CP), which contains traditional CP and emerging overthetop (OTT) content provider (OCP) such as Google, Amazon, and Netflix; network service provider (NSP); and equipment manufacturer (EM)

- Control plane consists of a set of distributed but logical centralized controllers. A controller can control a quantity of network entities, and a network entity can be controlled by different but logically centralized controllers.

- CN and RAN are included in forwarding plane. infrastructure of CN can be virtualized and controlled by control plane. centralized BBU pool and distributed RRHs of C-RAN are deployed to achieve efficient collaboration among different cells in HetNets

Application plane

- CP (e.g., OCP) distributes NDO in its server to end users with help of NSPs. objective/content information is decoupled from its location and sources by naming approach of ICN; thus, it is more suitable for CP to understand and forecast user behaviors (e.g., request frequency and content population distribution).

- Given service-level agreement (SLA) provided by different NSPs, CP chooses optimal NSPs via negotiation to distribute objective.

- Decoupling software and hardware via SDN mayhelp CPs and NSPs get rid of shackles of EM. It is not what EM wants, and negotiation protocol should also be developed among them. application requirements are negotiated based on protocol running in underlying control plane through open APIs.

Control plane

- Control plane running in a network operating system (NOS) is core part of architecture, and logically centralized controllers complete infrastructure virtualization, programming abstractions, and even content naming, addressing, and matching procedures for ICN.

- controller exploits complete knowledge of system and gets consolidated control functions to facilitate network reconfiguration and management via NOS.

- For example, wired backhual and wireless bandwidth owned by NSPs can be dynamically allocated to CPs and users, respectively, based on negotiation protocol running in controller.

Forwarding plane

- Forwarding plane consists of simplified and virtualized network devices that solely provide information switching and forwarding.
- HetNet may have tens of thousands of devices, and sheer number of control events generated at that scale is enough to overload any controller.
- Pushing all control functionality to centralized controllers makes them potential bottleneck.
- Propose to deploy wireless side of SDN in concept of CRAN where BBU pool has both control and data forwarding functions.
- Logically centralized BBU pool has a network-wide view of RAN and CN, yielding seamless integration of wired and wireless sides of SDN.
- Collaboratively controlled by controllers and BBU pool, NDO of ICN can be flexibly and optimally distributed and stored in diverse devices of CN and RAN via caching and broadcasting.

Data Offloading

Centralized BBU pool enables a Cloud-identification (ID)-enabled UE, connected via RRH, to directly connect to other UE configured with identical Cloud-ID without passing CN and Internet
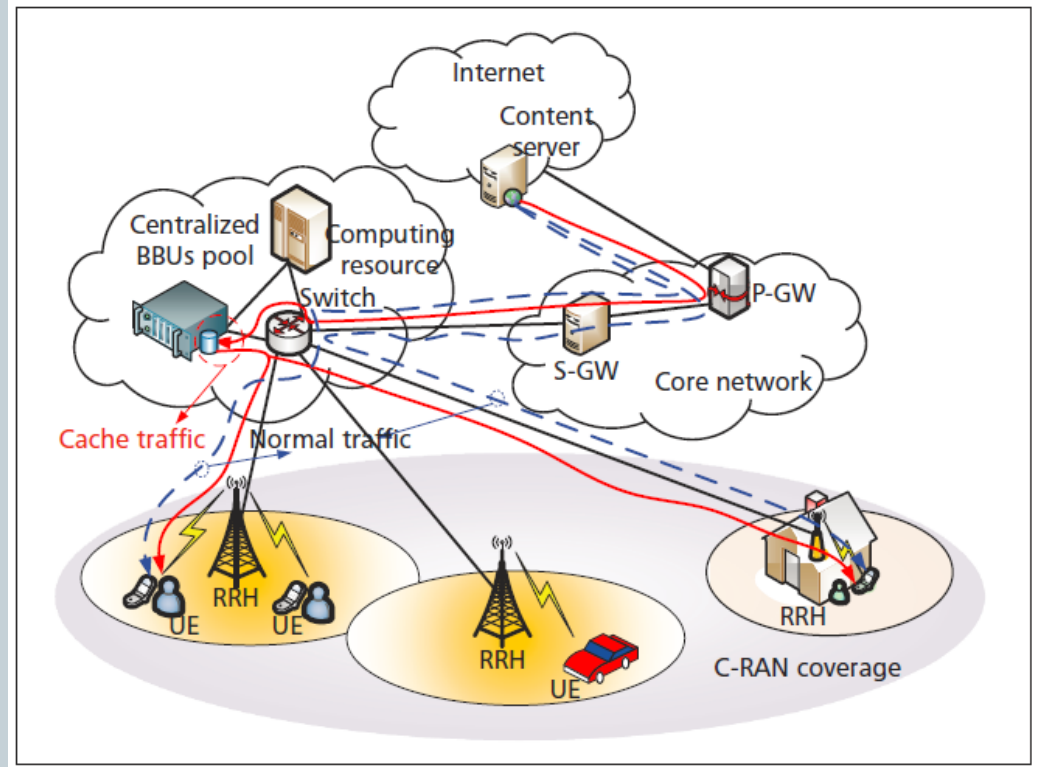
Offload traffic is established at RAN, and not a wireless local area network (WLAN).
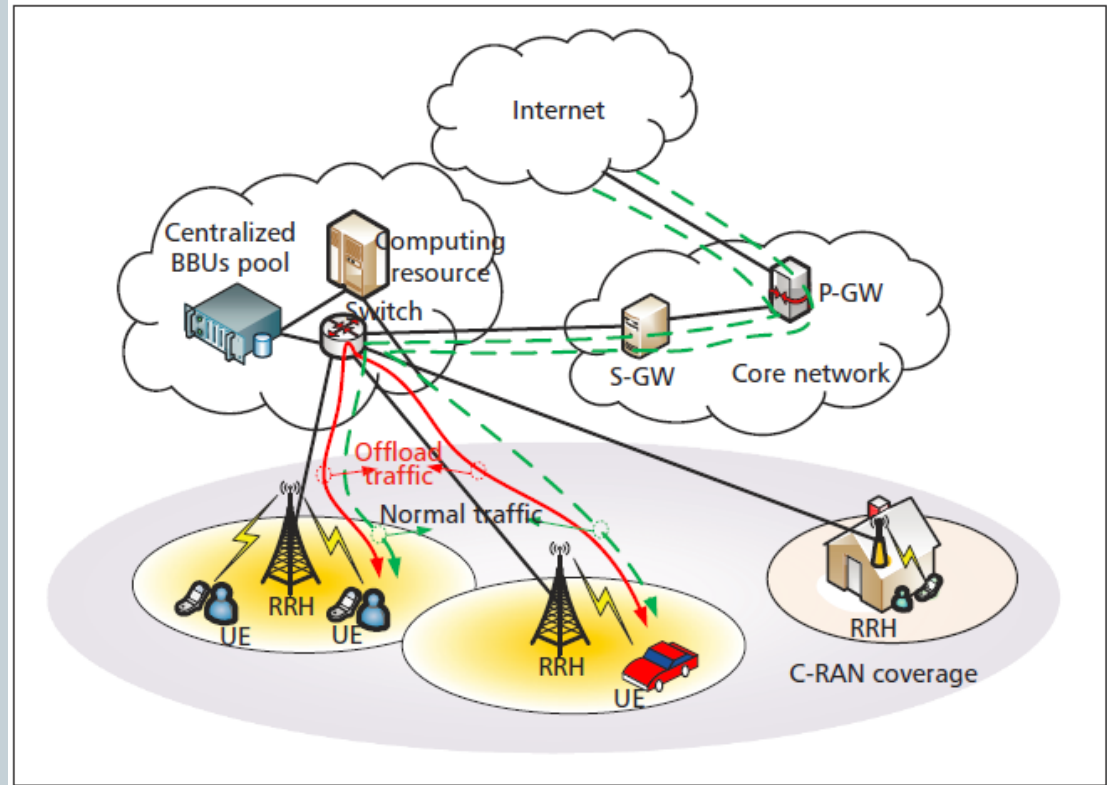
Caching

- When network is at off-peak traffic load (e.g., at night) most frequently accessed content can be broadcast and then cached at BBU pool

- Popular contents can also be pushed and cached in RAN or EPC when network is idle.
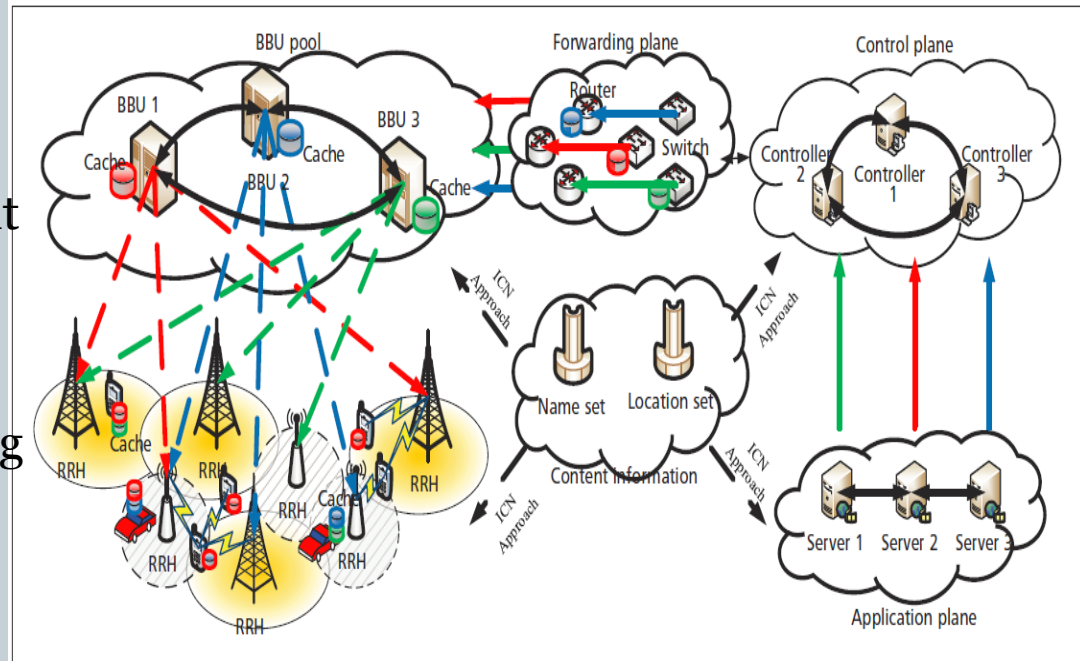
Coexisting system of SDN, ICN, and H-CRAN

Architecture Dimension: Infrastructures

•CPs provide services to subscribers with help of different NSPs based on negotiation protocol

•Controllers are between application plane and forwarding plane.

Information Dimension: Role NDO plays in ICN is as important as that IP plays in host-centric Internet.

•Information labeled with unique NDOs has been published by server in application plane or UE in RAN, its transcript can be held in cache enabled nodes (e.g., nodes in EPC or RAN) afterward.
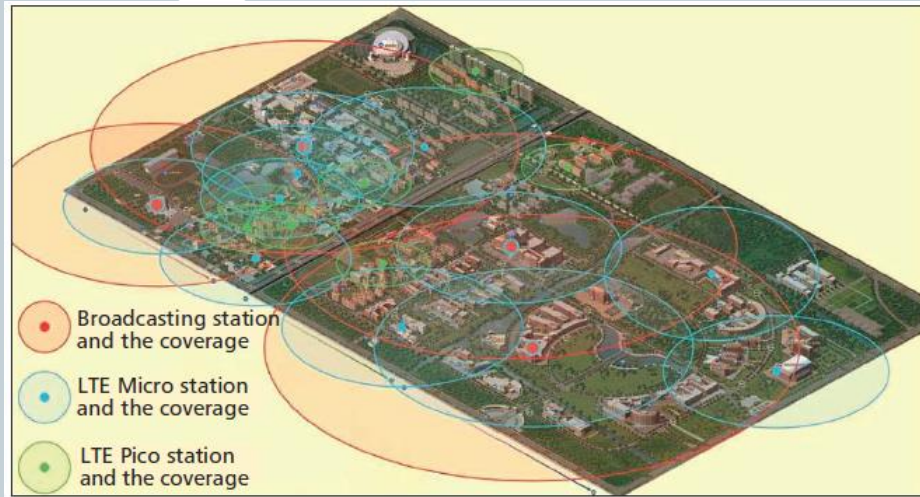
Challenges

- **Processing Overload:** Coordination in large-scale HetNets requires processing of very large network information such as channel matrices.

- One way to tackle this problem is to decrease redundant and duplicated flow before they enter control plan with appropriate strategy (e.g., optimal caching in ICN)

- **Backhual and Fronthaul:** common assumption that data can be routed to RANs without backhaul and fronthaul limitation is not valid for future high-density HetNet, where a large number of nodes need to access information.

- **Access Protocol and Data Routing: S**hould thus provide a uniform content distribution paradigm underlying all access protocols.

- Flexible and convenient information-aware mechanisms should be developed for data routing based on location-independent name of information.

Experimentation

- Large-scale wireless innovation campus network with 3 km2 coverage in Shanghai Jiao Tong University

- 80 LET micro and pico stations, 2500 WiFi access points

Broadcasting station and the coverage

LTE Micro station and the coverage

LTE Pico station and the coverage

Based on strategy developed by controllers, popular contents can be broadcast to cacheenabled nodes.
Cached content can be reused for frequent access.
Cellular communication, there is a D2D link (i.e., from cacheenabled users to requesting users) for content sharing, yielding a three-tier HetNet (i.e., micro BSs–users, pico BSs–users, D2D transmitters–users).

Results

- Throughput gain compared to baseline where there is no in-networking cache.
- Content access is triggered according to well-known Zipf distribution with parameter
- Larger g implies that fewer contents account for majority of requests.
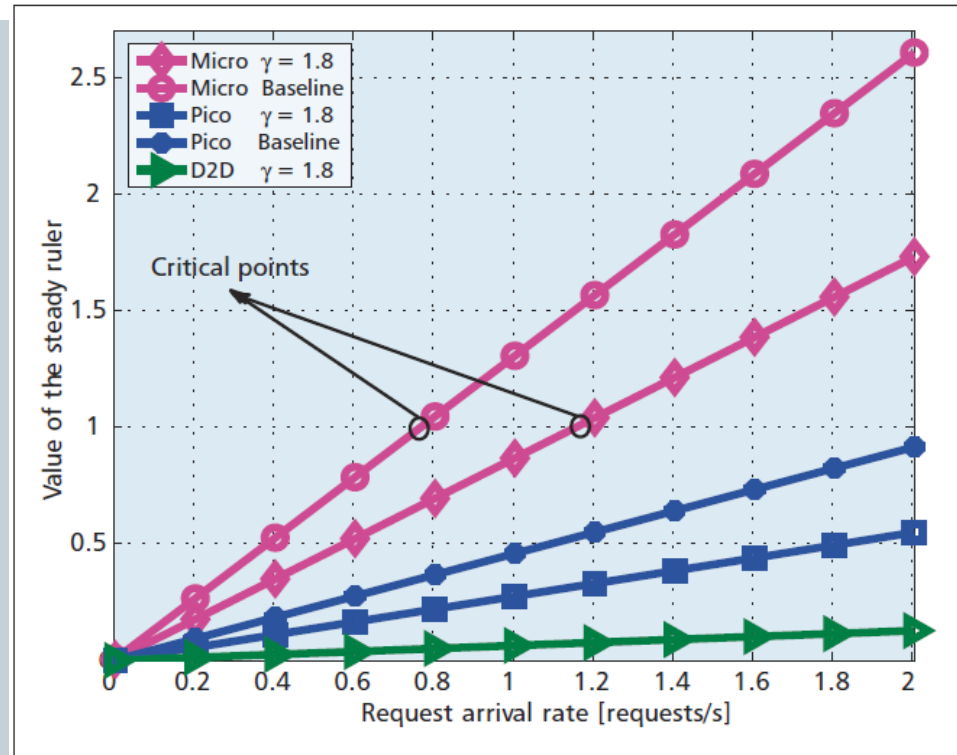
When g = 1.8 throughput gain is 53.9 percent that of baseline.

Pico and D2D tiers are far from fully loaded state when micro tier comes to critical steady state.

More appealing performance improvements can further be realized with appropriate resource scheduling and load balancing mechanisms.