Mobile CLOUD Computing

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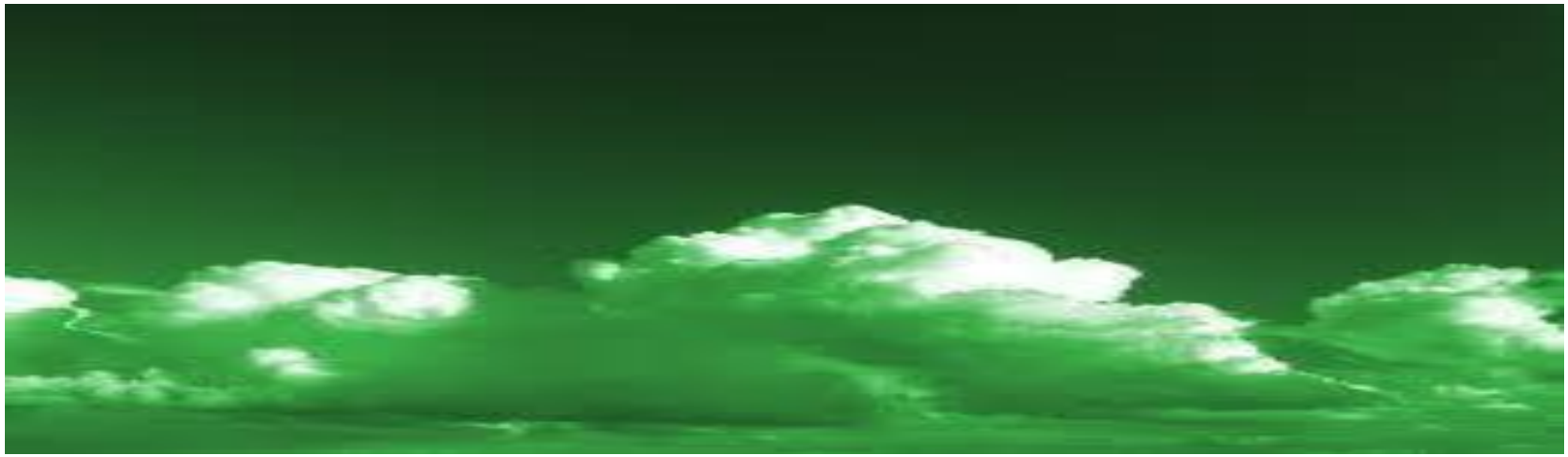
Outline of the talk..

- Cloud, mobile and computing - MCC
- MCC – introduction
- MCC – applications
- MCC – issues
- MCC - challenges



What is Mobile Cloud Computing?

- *Mobile cloud computing (MCC)* at its simplest, refers to an infrastructure where both the data storage and data processing happen outside of the mobile device.
- Mobile cloud applications move the computing power and data storage away from the mobile devices and into powerful and centralized computing platforms located in clouds, which are then accessed over the wireless connection based on a thin native client.

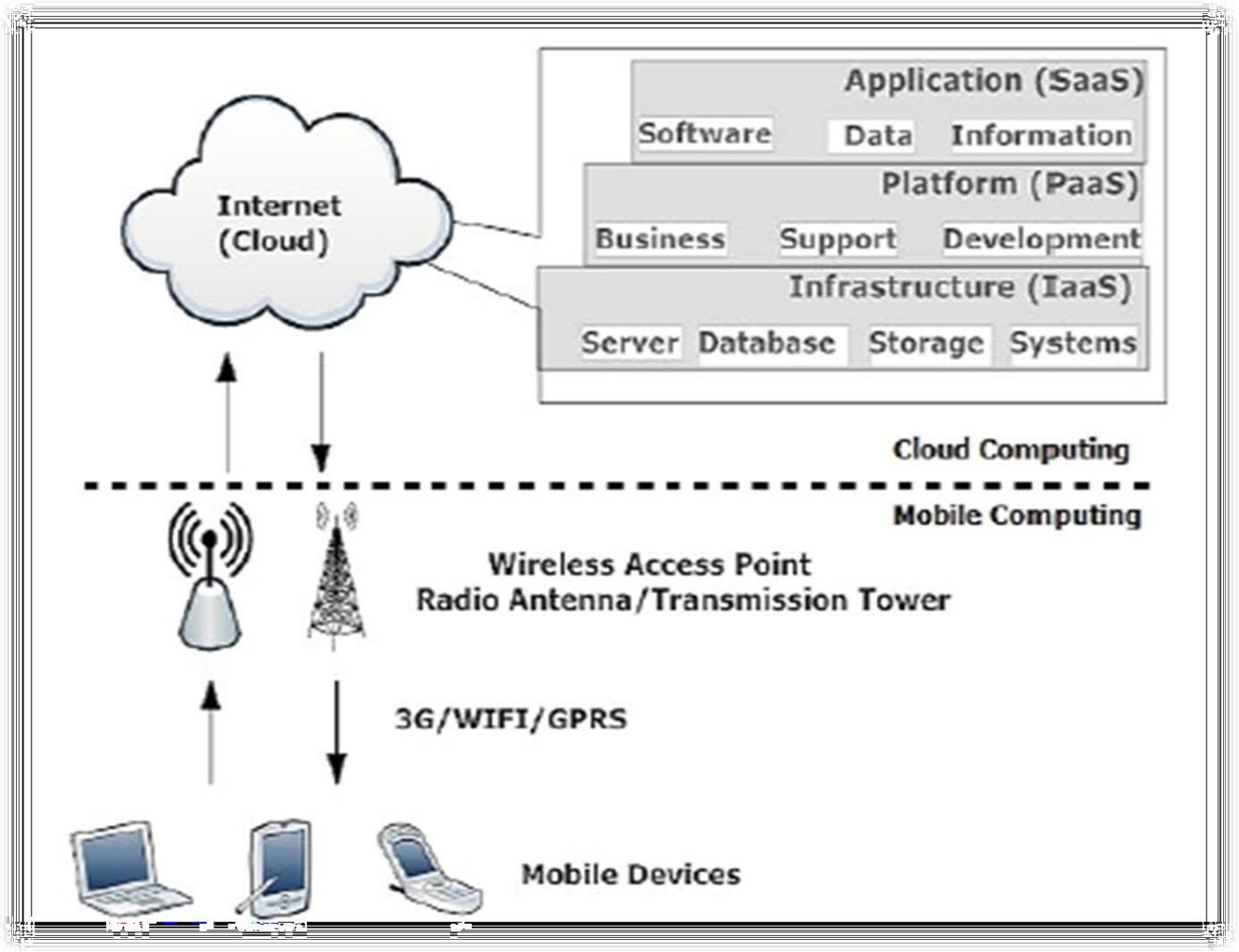
Cloud, Mobile and MCC

Cloud Computing – A paradigm of web-based computing where shared resources are provided on demand

Mobile Computing – Using portable devices to run standalone applications or use wireless media to access services

Mobile Cloud Computing – Augment mobile devices with content and processing capabilities using cloud

MCC - pictorial representation



Why Mobile Cloud Computing?

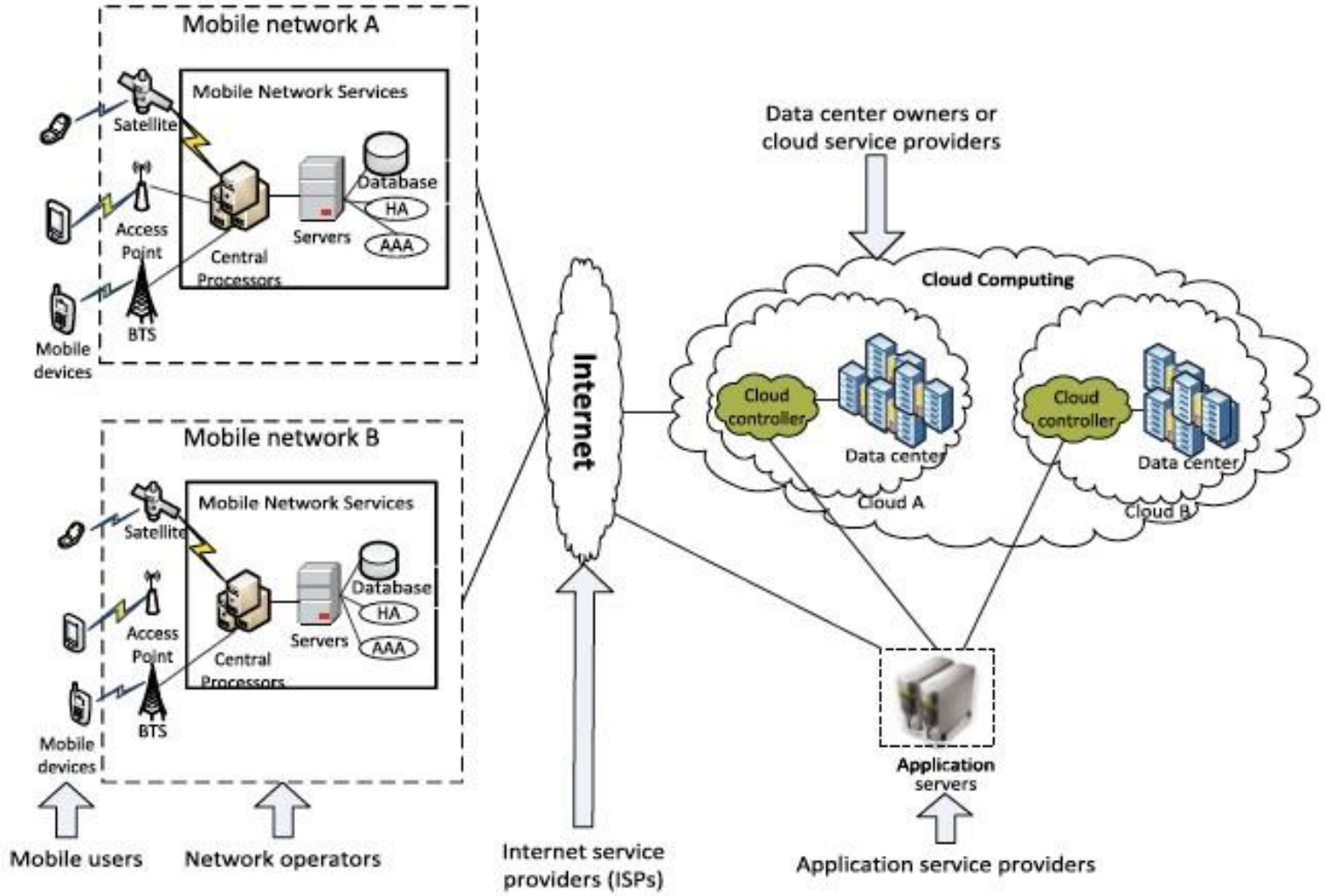
- Mobile devices face many resource challenges (battery life, storage, bandwidth etc.)
- Cloud computing offers advantages to users by allowing them to use infrastructure, platforms and software by cloud providers at low cost and elastically in an on-demand fashion.
- Mobile cloud computing provides mobile users with data storage and processing services in clouds, obviating the need to have a powerful device configuration (e.g. CPU speed, memory capacity etc), as all resource-intensive computing can be performed in the cloud.

MCC Popularity

- According to a recent study by ABI Research, more than 240 million business will use cloud services through mobile devices by 2015.
- That traction will push the revenue of mobile cloud computing to $5.2 billion.
- Mobile cloud computing is a highly promising trend for the future of mobile computing.

- Also – hosting of services, payment systems, analytics, application development and monitoring..

MCC Architecture



MCC Architecture

- Mobile devices are connected to the mobile networks via base stations that establish and control the connections and functional interfaces between the networks and mobile devices.
- Mobile users‟ requests and information are transmitted to the central processors that are connected to servers providing mobile network services.
- The subscribers‟ requests are delivered to a cloud through the Internet.
- In the cloud, cloud controllers process the requests to provide mobile users with the corresponding cloud services.

Advantages of MCC

- Extending battery lifetime:
  - Computation offloading migrates large computations and complex processing from resource-limited devices (i.e., mobile devices) to resourceful machines (i.e., servers in clouds).
  - Remote application execution can save energy significantly.
  - Many mobile applications take advantages from task migration and remote processing.

Advantages of MCC

- Improving data storage capacity and processing power:
  - MCC enables mobile users to store/access large data on the cloud.
  - MCC helps reduce the running cost for computation intensive applications.
  - Mobile applications are not constrained by storage capacity on the devices because their data now is stored on the cloud.

Advantages of MCC

- Improving reliability and availability:
  - Keeping data and application in the clouds reduces the chance of lost on the mobile devices.
  - MCC can be designed as a comprehensive data security model for both service providers and users:
    - Protect copyrighted digital contents in clouds.
    - Provide security services such as virus scanning, malicious code detection, authentication for mobile users.
  - With data and services in the clouds, then are always(almost) available even when the users are moving.

Advantages of MCC

- Dynamic provisioning:
  - Dynamic on-demand provisioning of resources on a fine-grained, self-service basis
  - No need for advanced reservation
- Scalability:
  - Mobile applications can be performed and scaled to meet the unpredictable user demands
  - Service providers can easily add and expand a service

Advantages of MCC

- Multi-tenancy:
  - Service providers can share the resources and costs to support a variety of applications and large no. of users.

- Ease of Integration:
  - Multiple services from different providers can be integrated easily through the cloud and the Internet to meet the users‟ demands.

MCC Applications

- Mobile Commerce:
  - M-commerce allows business models for commerce using mobile devices.
  - Examples: Mobile financial, mobile advertising, mobile shopping…
  - M-commerce applications face various challenges (low bandwidth, high complexity of devices, security, …)
  - Integrated with cloud can help address these issues
  - Example: Combining 4G/5G and cloud to increase data processing speed and security level.

MCC Applications

- Mobile Learning:
  - M-learning combines e-learning and mobility
  - Traditional m-learning has limitations on high cost of devices/network, low transmission rate, limited educational resources
  - Cloud-based m-learning can solve these limitations
  - Enhanced communication quality between students and teachers
  - Help learners access remote learning resources
  - A natural environment for collaborative learning

MCC Applications

- Mobile Healthcare:
  - M-healthcare is to minimize the limitations of traditional medical treatment (eg. Small storage, security/privacy, medical errors, …)
  - M-healthcare provides mobile users with convenient access to resources(eg. medical records)
  - M-healthcare offers hospitals and healthcare organizations a variety of on-demand services on clouds
  - Examples:
    - Comprehensive health monitoring services
    - Intelligent emergency management system
    - Health-aware mobile devices (detect pulse-rate, blood pressure, level of alcohol etc)
    - Pervasive access to healthcare information
    - Pervasive lifestyle incentive management (to manage healthcare expenses)

MCC Applications

- Mobile Gaming:
  - M-game is a high potential market generating revenues for service providers.
  - Can completely offload game engine requiring large computing resource (e.g., graphic rendering) to the server in the cloud.
  - Offloading can also save energy and increase game playing time (eg. MAUI allows fine-grained energy-aware offloading of mobile codes to a cloud)
  - Rendering adaptation technique can dynamically adjust the game rendering parameters based on communication constraints and gamers‟ demands

MCC Applications

- Assistive technologies:
  - Pedestrian crossing guide for blind and visually-impaired
  - Mobile currency reader for blind and visually impaired
  - Lecture transcription for hearing impaired students
- Other applications:
  - Sharing photos/videos
  - Keyword-based, voice-based, tag-based searching
  - Monitoring a house, smart home systems
  - …

MCC Issues

- Mobile communication issues:
  - Low bandwidth: One of the biggest issues, because the radio resource for wireless networks is much more scarce than wired networks
  - Service availability: Mobile users may not be able to connect to the cloud to obtain a service due to traffic congestion, network failures, mobile signal strength problems
  - Heterogeneity: Handling wireless connectivity with highly heterogeneous networks to satisfy MCC requirements (always-on connectivity, on-demand scalability, energy efficiency) is a difficult problem

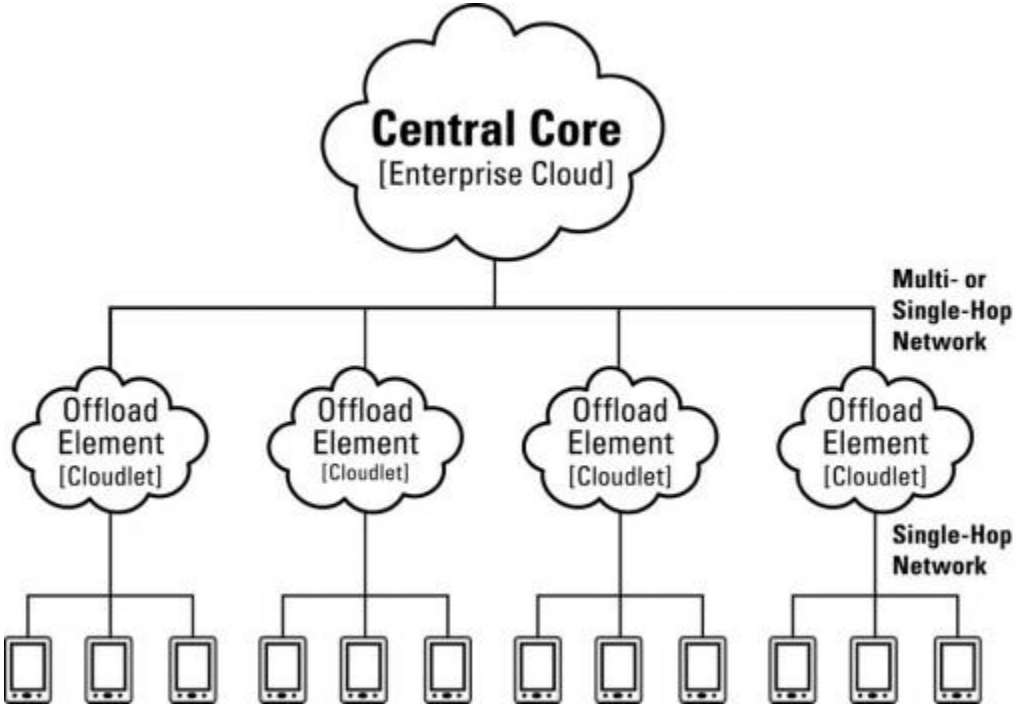
MCC Issues

- Computing issues:

  Computation offloading:

  - One of the main features of MCC
  - Offloading is not always effective in saving energy
  - It is critical to determine whether to offload and which portions of the service codes to offload
  - Two types:
    - Offloading in a static environment
    - Offloading in a dynamic environment

Offload mechanism



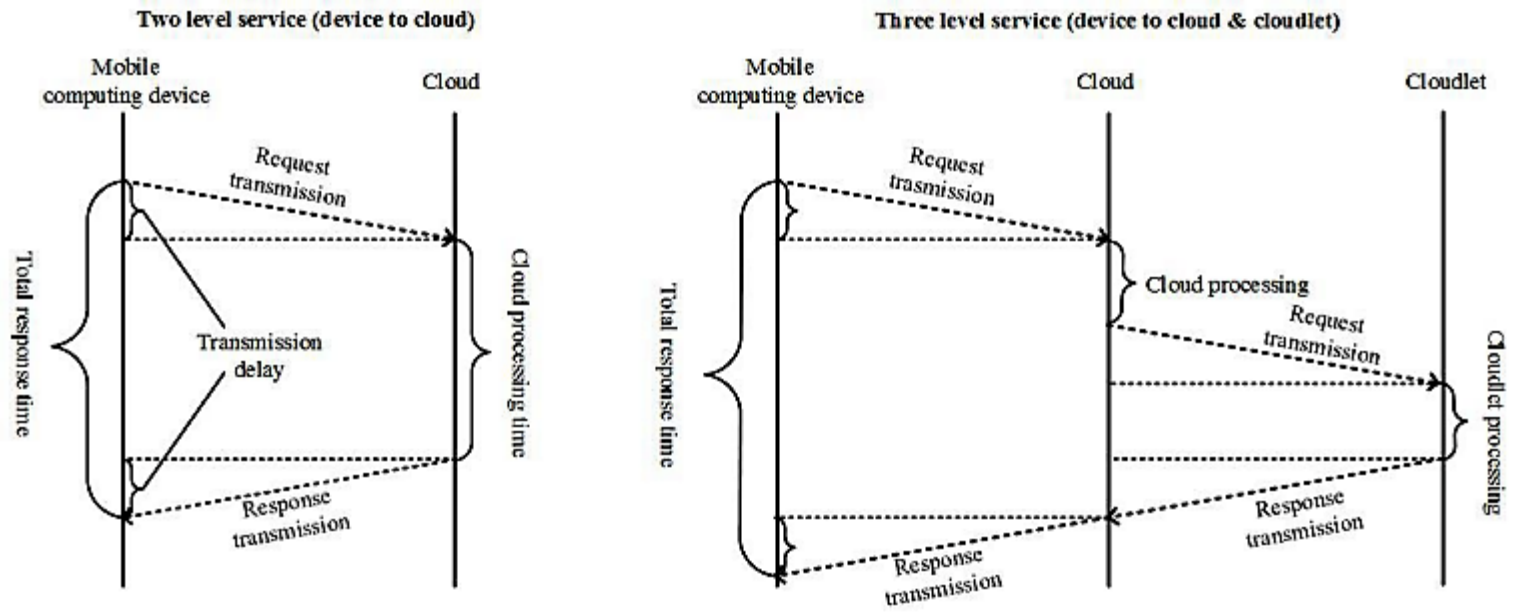


FIGURE 4. Offloading scenarios.

Computation Offloading Approaches in a Static Environment

- Kumar and Lu suggest a program partitioning based on estimation of energy consumption before execution
- Optimal program partitioning for offloading is dynamically calculated based on the trade-off between the communication and computation costs at run time.

K. Kumar and Y. Lu, “Cloud Computing for Mobile Users: Can Offloading Computation Save Energy,”

IEEE Computer, vol. 43, no. 4, April 2010.

Computation Offloading Approaches in a Static Environment

- Li et al. present an offloading scheme based on profiling information about computation time and data sharing at the level of procedure calls.
- A cost graph is constructed and a branch-and-bound algorithm is applied to minimize the total energy consumption of computation and the total data communication cost.

Z. Li, C. Wang, and R. Xu, “Computation offloading to save energy on handheld devices: a partition scheme,” in Proc 2001 Intl Conf on Compilers, architecture, and synthesis for embedded systems (CASES), pp. 238-246, Nov 2001.

Computation Offloading Issues in a Dynamic Environment

•Offloading in a dynamic network environment (e.g., changing connection status and bandwidth) is harder.

- Environment changes can cause additional problems.
- The transmitted data may not reach the destination
- The data executed on the server could be lost when it has to be returned to the sender.

Computation Offloading Approaches in a Dynamic Environment

- Ou et al. analyze offloading systems in wireless environments
- They consider three circumstances of executing an application to estimate the efficiency of offloading.
  - performed locally (without offloading)
  - performed in ideal offloading systems (without failures)
  - performed with the presence of offloading and failure recoveries (re-offload after failure)

S. Ou, K. Yang, A. Liotta, and L. Hu. “Performance Analysis of Offloading Systems in Mobile Wireless Environments,” in Proc IEEE Intl Conf on Communications (ICC), pp. 1821, August 2007.

MCC Security Issues

- Protecting user privacy and data/application secrecy from adversaries is key to establish and maintain consumers‟ trust in the mobile platform, especially in MCC.

- MCC security issues have two main categories:
  - Security for mobile users
  - Securing data on clouds

Security for Mobile Users

- Mobile devices are exposed to numerous security threats like malicious codes and their vulnerability.
- GPS can cause privacy issues for subscribers.
- Security for mobile applications:
  - Installing and running security software are the simplest ways to detect security threats.
  - Mobile devices are resource constrained, protecting them from the threats is more difficult than that for resourceful devices.

Privacy Issues in MCC

- Location based services (LBS) faces a privacy issue on mobile users‟ provide private information such as their current location.

- This problem becomes even worse if an adversary knows user‟s important information.

Context-aware Mobile Cloud Services

- It is important to fulfill mobile users‟ satisfaction by monitoring their preferences and providing appropriate services to each of the users.

- Context-aware mobile cloud services try to utilize the local contexts (e.g., data types, network status, device environments, and user preferences) to improve the quality of service (QoS).

Mobile Service Clouds

- When a customer uses a service, the request firstly goes to a service gateway which will choose an appropriate primary proxy to meet the requirements and then sends the result to the user.
- In disconnection, MSCs will establish transient proxies for mobile devices to monitor the service path, and support dynamic reconfiguration.
- The model addresses the disconnection issue and can maintain the QoS at an acceptable level.

Open Issues in MCC

- Network Access Management:
  - An efficient network access management not only improves link performance but also optimizes bandwidth usage.
  - Cognitive radio can be expected as a solution to achieve the wireless access management.
  - Can automatically changes its transmission or reception parameters, in a way where the wireless communications can have spectrum agility in terms of selecting available wireless channels opportunistically.
  - Integrated with MCC for better spectrum utilization

Open Issues in MCC

- Quality of Service:
  - How to ensure QoS is still a big issue, especially on network delay.
  - CloneCloud and Cloudlets are expected to reduce the network delay.
  - CloneCloud uses nearby computers or data centers to increase the speed of smart phone applications.
  - The idea is to clone the entire set of data and applications from the smartphone onto the cloud and to selectively execute some operations on the clones, reintegrating the results back into the smartphone.

Open Issues in MCC

- Quality of Service:
  - A cloudlet is a trusted, resource-rich computer or cluster of computers which is well-connected to the Internet and available for use by nearby mobile devices with on one-hop wireless connection.
  - Mobile users may meet the demand for real-time interactive response by low-latency, one-hop, high-bandwidth wireless access to the cloudlet.
  - Can help mobile users overcome the limits of cloud computing as WAN latency and low bandwidth.

Open Issues in MCC

- Pricing:
  - MCC involves with both mobile service provider (MSP) and cloud service provider (CSP) with different services management, customers management, methods of payment and prices.
  - This will lead to many issues.
  - The business model including pricing and revenue sharing has to be carefully developed for MCC.

Open Issues in MCC

- Standard Interface:
  - Interoperability becomes an important issue when mobile users need to interact with the cloud.
  - Web interfaces may not be the best option.
  - It is not specifically designed for mobile devices.
  - May have more overhead.
  - Compatibility among devices for web interface could be an issue.
  - Standard protocol, signaling, and interface for interacting between mobile users and cloud would be required. (HTML5 & CSS3)

Open Issues in MCC

- Service Convergence:
  - Services will be differentiated according to the types, cost, availability and quality.
  - A single cloud may not be enough to meet mobile user‟s demands.
  - New scheme is needed in which the mobile users can utilize multiple cloud in a unified fashion.
  - The scheme should be able to automatically discover and compose services for user.
  - Sky computing is a model where resources from multiple clouds providers are leveraged to create a large scale distributed infrastructure.
  - The mobile sky computing will enable providers to support a cross-cloud communication and enable users to implement mobile services and applications.
  - Service integration (i.e., convergence) would need to be explored.

THE CONVERGENCE OF MOBILE NETWORK AND SERVICE PROVIDER