Adaptive Cross-layer QoS Mechanism for Cognitive Network Applications

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Abstract- **Given limited network resources, applications, particularly those that support real-time services, must deliver an ambient quality-guaranteed service. Different applications are associated with different Quality of Service (QoS) concerns, as well as different QoS control parameters. This work discusses the QoS specifications of three wireless access technologies, 3G, WiMAX and WiFi, in the design of an ambient QoS mechanism. By exploiting the concepts of Cross-Layer and Cognition, this study integrates these environmental parameters with the sensing of spectral and received signal strength from a cognitive radio paradigm, and proposes the ambient QoS algorithm to select the best access network for services. The proposed QoS mechanism not only meets the requirements of various applications but also guarantees QoS. From the simulation results, the proposed ambient QoS mechanism outperforms existing mechanisms in real-time applications. Comparison with traditional mechanisms reveals that the proposed ambient intelligence reduces average delay time and jitter to 0.157 seconds and 0.086 milliseconds, respectively, for VoIP services, and reduces the packet loss ratio for high-definition video stream by 3.42%.**

***Keywords*—Heterogeneous Network, Quality of Service, Ambient Intelligence, Cross-Layer, Cognitive Network**

I. INTRODUCTION

The rapid development of the Internet is driving daily changes in wireless communication and mobile computing technologies. Mobile communication and service providers suffer from heterogeneous network environments. Consequently, supporting ambient Quality of Service (QoS) is importance to next generation wireless communication.

Figure 1 presents the promising 4G heterogeneous network architecture which includes 3G, WLAN and WiMAX access technologies. The IMS (IP Multimedia Subsystem) fulfills three main functions in the packet switching core network, including providing QoS for services, offering extensible charging mechanisms to multimedia services and integrating All-IP services.

Spectral resources have become increasingly limited owing to the rapid development of wireless communication technology, especially the frequencies below 3 GHz. Cognitive radio (CR) is a key technology for improving spectrum-utilization efficiency under the current static spectrum-allocation policy [1, 2]. CR is a wireless communication paradigm in which either a network or a wireless node changes its transmission to increase communication efficiency. The CR allows user terminals to sense whether a portion of the spectrum is being used, thus facilitating spectrum sharing among neighboring users.

Layering is fundamental in providing the basis for protocol design. System designers can divide a complicated architecture into modules and solve each one independently. Stressing the concept of modular design leads to major communication and only occurs between nearby layers, and causes problems in transmission performance, such as high error rate in wireless networks, security, QoS and power consumption of mobile communications. Hence, an ambient mechanism, Cross-Layer scheme, can enhance transfer efficiency and networking performance.

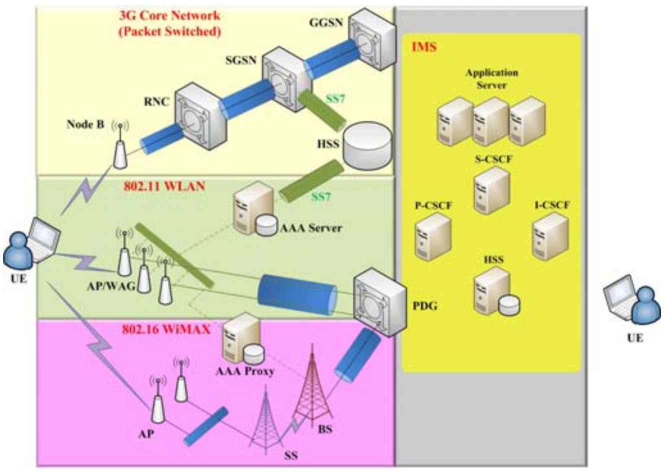

Figure 1: 4G Network Architecture

Based on the cross-layer, cognitive and cooperative operating concepts, this study proposes an ambient QoS architecture for 4G network services. Figure 2 presents the proposed C^3QM (Cross-layer, Cognitive, Cooperative QoS Manager) system architecture. The system architecture includes the Data Plane, Control Plane and Knowledge Plane. The Data Plane primarily collects network status or parameters and then provides Control Plane and Knowledge Plane data for analysis and management, respectively; the Control Plane analyzes data transferred from the Data Plane and delivers the decision results regarding the ambient QoS mechanism to the Knowledge Plane; the Knowledge Plane then defines different QoS goals from the low-layer information and communicates with other agents using a cooperative strategy.

This paper introduces the functional modules, illustrated in the dark color in Fig. 2, and applications. Integrating the built modules, an ambient QoS mechanism with cross-layer and cognitive concepts is developed.

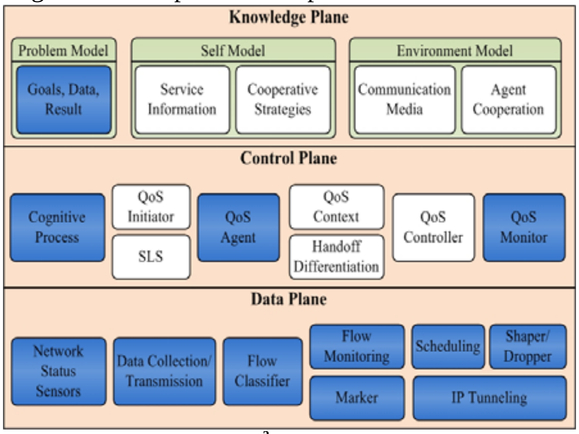

Figure 2: Proposed C^3QM Ambient Architecture

II. PRIOR ART

The IP Multimedia Subsystem (IMS) has been recognized as an integral component in the Next Generation Networks and become to an All IP environment [3]. The UCT Policy Control Framework has distributed architecture that designed for QoS provisioning in the IMS. The architecture is based on the 3GPP PCC system and defines a Policy Decision Function (PDF), Policy Enforcement Point (PEP), Policy Repository and Web Management interface [4]. The PDF creates the QoS policy rules that provided synchronization and linkage between the signaling and transport layers. The PEP resides in the transport layer, and receives the QoS policy rules that transport specific configuration information.

Cognitive network is a network architecture based on cognitive radio. Mitola and Maguire were the first to describe CR. They see the CR, built on a software-defined radio, as an intelligent wireless communication system [5]. Haykin defines CR as an intelligent wireless communication system that is aware of its surrounding environment, and uses understanding-by-building to learn from that environment and adapt its internal states to statistical variations in incoming RF stimuli by adjusting operating parameters (e.g., transmit-power, carrier-frequency, and modulation strategy) in real-time [6].

While short-term fading effects should be fixed within a layer, long-term fading effects must be addressed to the application layer [7]. A strict layered design thus may not be sufficiently flexible for use in varied wireless environments. Many case studies have been introduced including AMC (Adaptive Modulation/ Coding) with ARQ (Automatic Repeat reQuest) system, ECN (Explicit Congestion Notification) Bit system and WQE (Wireless Quality Enhancer) system respectively [8-10].

Related researches exist in relation to cognitive radio network. Cognitive Radio technology recently has become extremely popular because of its frequent utilization. To improve the performance of spectrum sharing between primary and cognitive radio systems, scheduling algorithms are examined to allow cognitive users to dynamically access available channels in which they need to operate.

The existing research proposes a cross-layer opportunistic scheduling algorithm with efficient interference control at the MAC layer for multiclass cognitive users with diverse QoS requirements, where each connection employs an AMC scheme at the PHY layer. Simulation results show that the scheduler can guarantee individual QoS requirements, improve fairness, use bandwidth efficiently and significantly mitigate the interference to the primary user without losing significant QoS [11].

The existing research proposes implementing of the Resource Admission Control Subsystem (RACS) in IMS using CR to achieve the required flexibility in resource allocation across different networks. The ultimate result of this implementation is that the scope of the RACS is significantly increased, as is resource reservation and QoS management by the RACS [12].

III.PROPOSED AMBIENT QOS MECHANISM

To support QoS services in mobile internet, issues related to heterogeneity and mobility must be solved to satisfy user requests. Since they roam among network domains, users interact with different service providers according to network overhead, network topology, policies (QoS, security, handover) and so on. Therefore, it is necessary to provide alternative channels or network access technologies even though it complicates end-to-end service.

Cross-layer ambient networking can solve the problem of wireless channel fading. Cross-layer design also facilitates efficient allocation of network resources and applications over wireless communication environments. Figure 3 shows the proposed cross-layer QoS concept, which retrieves the information from the Link and Application Layers and returns the decision-making state variables to each layer to handle operations.

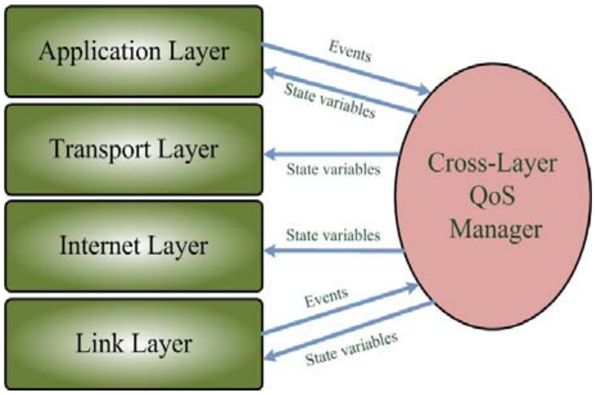

Figure 3: Proposed Ambient Cross-Layer QoS Concept

Figure 4 illustrates the proposed cross-layer ambient QoS manager system architecture, which includes the Data Plane, Control Plane and Knowledge Plane. The Data Plane primarily gathers network status and parameters, manages incoming traffic and provides the information to the Control Plane and the Knowledge Plane for analysis and management; meanwhile, the Control Plane judges whether the resource is sufficient for allocation to the requested connection, manages the handover process and responds by transferring the control signal to each layer; the Knowledge Plane defines different QoS goals from low layer information and makes handover decisions involving appropriate access networks based on the proposed ambient QoS algorithm.

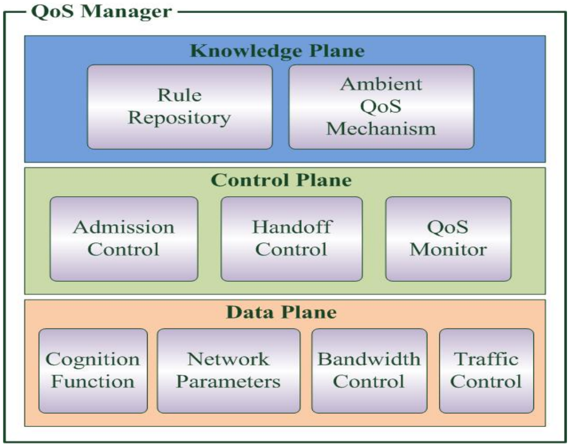

Figure 4: Proposed Ambient QoS Manager System Architecture

Figure 5 describes the ambient QoS algorithm. The mobile node checks its environment for available networks. For each available network, the ambient QoS algorithm checks the application type and maps it to the appropriate traffic class. Four traffic classes are defined, including Interactive Class, Conversation Class, Video/Audio Streaming Class and Best Effort Class. The Conversation Class traffic, such as VoIP stream, is more concern about the jitter. Excessive jitter distorts voice conversation. The Video/Audio Streaming Class traffic, such as MPEG video suffers issues of packet loss. Video quality is reduced if the packet loss ratio exceeds a pre-defined threshold.

The ambient QoS algorithm judges the QoS parameters and bandwidth of the candidate networks. If the candidate network status satisfies the user requests, the mobile node performs the handover procedure, and moves to the candidate network to obtain better QoS. If the mobile node has two or more candidate networks that satisfy user QoS requests, the ambient QoS algorithm selects that with the highest RSSI value as the candidate network. Figure 6 shows the flow chart of the ambient QoS algorithm.

```
Check available network & store in AN[i]
if ( i ≧ 0 )
{
    for ( index = 0; index ≦ i; index++ )
    {
        switch (traffic_class)
        {
            case  #2:
                if ( J_AN[i]==NULL )
                {
                    flag[i]=0;
                    break;
                } else if ( J_thd ≧ J_AN[i] && B_req ≦ B_AN[i] )
                    flag[i] = 1;
                break;
            case  #3:
                if ( PLR_AN[i]==NULL )
                {
                    flag[i]=0;
                    break;
                } else if ( PLR_thd ≧ PLR_AN[i] && B_req ≦ B_AN[i] )
                    flag[i] = 1;
                break;
            default:
                flag[i] = 0;
        }
    }
    if ( exist i when flag[i]==1 && max(RSSI_AN[i]) )
    {
        B_AN[i] − = B_req;
        return candidate network AN[i]
    }else
        {
            if ( RSSI_cur  <  max(RSSI_AN[i]) )
                return AN[i] which has max(RSSI_AN[i])
            else
                Using current network!!
        }
}else
    No available network!!
```

Figure 5: Ambient QoS Algorithm

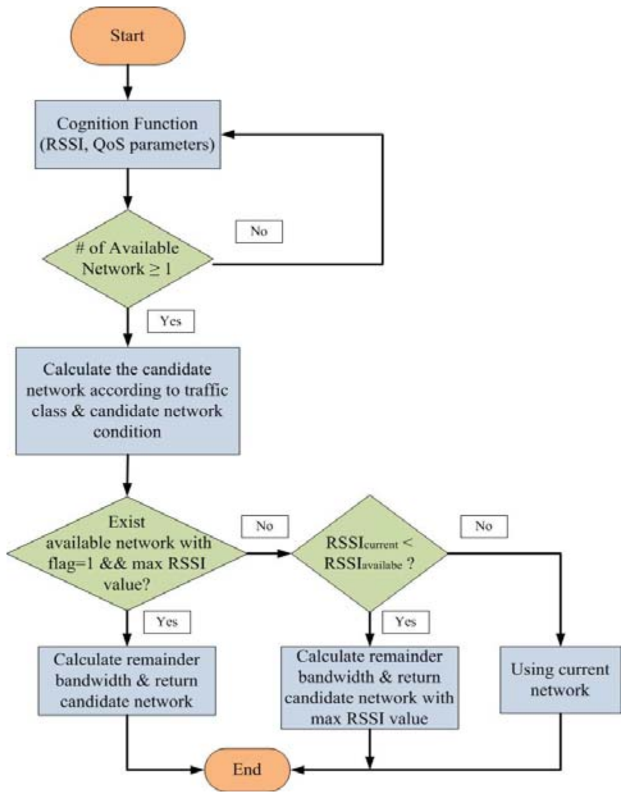

Figure 6: Flow Chart of Ambient QoS Algorithm

IV. PERFORMANCE ANALYSIS

This section introduces the performance metrics used to assess the proposed ambient QoS mechanism. The proposed mechanism is compared with that without ambient QoS algorithm. Performance measured using the two mechanisms are then discussed below.

A. Performance Metrics

Four analyses are performed to assess the performance of the proposed ambient QoS mechanism. The analyses include average delay time, jitter, packet loss and system throughput. The performance parameters are listed below.

- Average delay time is defined as the average time between a packet being transmitted from the source-end and received by the sink.
- Jitter, also called packet delay variation, denotes the difference in end-to-end delay between selected packets transferred from the source to the destination.
- Packet loss denotes the number of packets sent from the source minus the number of packets received from the destination.
- Throughput which is expressed in data units per time period represents the number of bytes passing through a data communication system.

Figure 1 illustrates the network simulation environment, including network topology and link. The network simulation environment has 3G, WiMAX and WiFi, with bandwidth capacity of 2Mbps, 14Mbps and 54Mbps, respectively. The UMTS/Node B, 802.16BS and 802.11AP are connected to ambient QoS Manager with 20Mbps wired link. The link capacity between the Manger and CN (Corresponding Node) is 8Mbps.

The traffic types include VoIP and Video stream. The VoIP has 200 bytes per packet, data rate of 64 kbps, arrival time at 2.0+ intervals and stop time on 120 seconds. The Video stream has 1500 bytes per packet, data rate of 256 kbps, arrival time at 5.0+ intervals and stop time on 120 seconds. The number of UE in the time sequence is shown in Fig. 7.

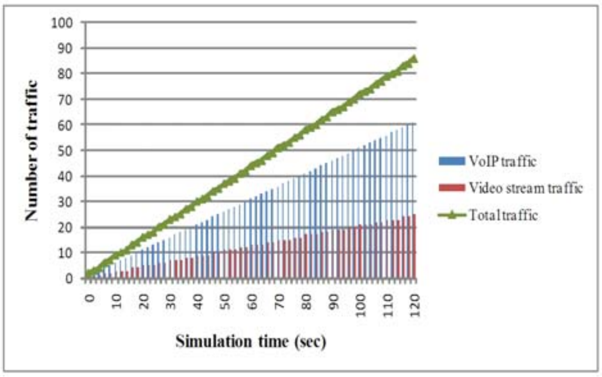

Figure 7: Number of UE in the Time Sequence

B. Analysis Results

The analysis results are listed below. In Fig. 8, the VoIP delay time with ambient QoS mechanism is lower than that without ambient QoS mechanism. Because the proposed ambient QoS algorithm selects the best network for video stream services based on the available service networks, the delay time of video stream with ambient QoS mechanism is higher than that without ambient QoS mechanism.

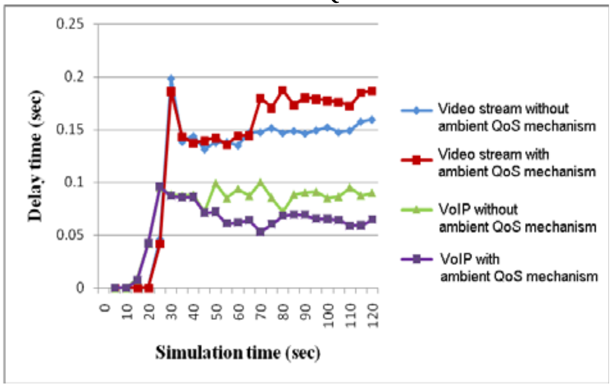

Figure 8: Delay Time

In Fig. 9, the VoIP jitter with ambient QoS mechanism is more stable than that without ambient QoS mechanism. Because the proposed algorithm can monitor and evaluate the candidate networks, it selects the best network for VoIP traffic according to its QoS request.

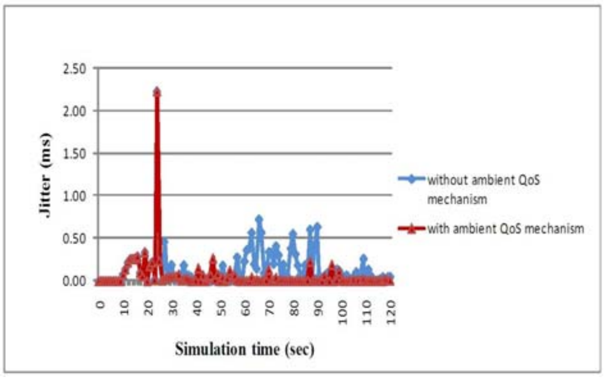

Figure 9: VoIP Jitter

In Fig. 10, the packet loss ratio of video stream with ambient QoS mechanism is lower than that without ambient QoS mechanism. The simulation result demonstrates that the proposed ambient QoS algorithm can effectively select the better network for video stream services. It also indicates that the packet loss ratio of VoIP stream with ambient QoS mechanism exceeds that of VoIP stream without ambient QoS mechanism by about 1.8%. However, VoIP stream with ambient QoS mechanism has lower delay time than that without ambient QoS mechanism.

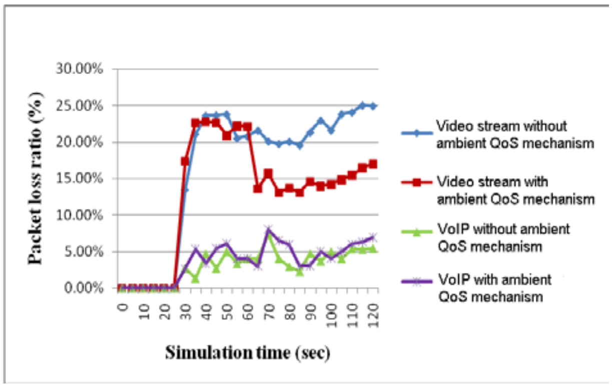

Figure 10: Packet Loss Ratio

Figure 11 illustrates the system throughput. The result shows that the throughput with and without ambient QoS mechanism is almost identical. However, VoIP traffic with ambient QoS mechanism has more stable jitter, and video stream with ambient QoS mechanism has lower packet loss ratio.

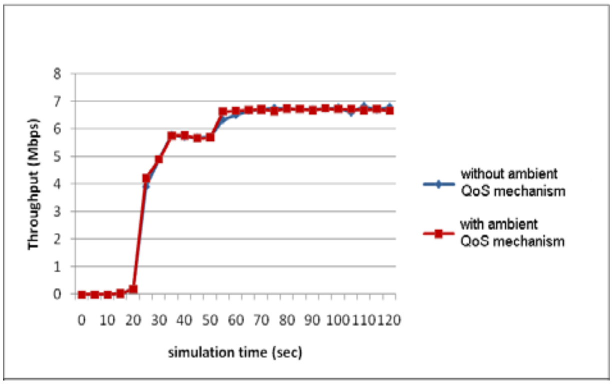

Figure 11: System Throughput

Table 1 shows that the performance with the proposed ambient QoS mechanism is better than that without the ambient QoS mechanism for the specified QoS of each application.

Table 1: Performance Improvement

Traffic Type	Decrease/ Increase	QoS Concern	Improvement (Average)
VoIP	Decrease	Delay Time	0.157(sec)
VoIP	Decrease	Jitter	0.086(ms)
Video Stream	Decrease	Packet Loss Ratio	3.42%

V. Conclusions

Because of the accelerated development of the Internet, various wireless communication technologies and mobile computing technologies are presently in use. In the future, heterogeneous networks with dynamic changing network access techniques must be adopted to improve the usage of network resources. This study proposes ambient cross-layer architecture with three planes- Data Plane, Control Plane and Knowledge Plane. The proposed ambient QoS mechanism uses the RSSI value and channel sensing in the Link layer and the QoS request in the Application layer to find the candidate service network. The proposed mechanism selects the best available network to guarantee QoS. Simulation results show that VoIP traffic with an ambient QoS mechanism has a stability jitter and that video streams with the ambient QoS mechanism have lower packet loss ratios.

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