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Railway Communication Network: A Case Study for Mobile Quality of Service

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***Abstract*— Trains, nowadays, are becoming a popular choice for a fast, comfortable, and cheaper way to travel. Train's passengers on a long journey tend to occupy their time by accessing content through mobile devices. Cisco predicted Smartphone traffic will exceed PC traffic by 2020 [1]. With the increasing growth of content exchanged, there is a rising demand for managing content for mobile users. Without a significant improvement in railway network infrastructure, the Quality of Service (QoS) for communication in-carriage will degrade, compromising passengers' experience in mobile communication. Moreover, due to the nature of the railway network that has to support a large group of users in a long journey period, the requested contents are usually bandwidth-intensive with the need for continuous mobility support. In order to ensure mobile Quality of Service (mQoS), intelligent & dynamic content management is required to facilitate content distribution. Currently implemented a method to manage mobility heavily relies on a host-to-host connection. A proposal by Future Internet Architecture introduces content-centric networking with built-in mobility. The present paper consider scalability and QoS in high-speed mobility. Therefore, by using a content-centric network proposal, this research aims to propose railway communication networks that provide the solution of mobile QoS.**

Keywords— Railway Communication Network, Content-Centric Network, Quality of Service.

I. INTRODUCTION

Massive public transportation, such as trains, has an important role in our daily life that allows a fast, comfortable, and cheaper way to travel. Railway infrastructure brings benefits by accommodating transportations in relatively wide areas and with a large group of users. Railway becomes a more popular choice of transportation since it promotes a more reliable and predicted timetable compared to road and/or highway. With the growth of railway infrastructure, it is anticipated to increase the number of train passengers. Current mobility trends show user exchanging contents "on the go", leading to an exponential growth of demand in mobile communication. Without a proper improvement in the railway communication network, the quality of service for passengers in a moving mobile environment will degrade.

Due to a rapid increase of multimedia traffic and content sharing demands, it is necessary to shift from the current end-to-end host-centric to content-centric connection. Content-Centric Network (CCN) is a Future Internet Architecture that shifts the communication paradigm from today's focus on "where" (addresses, servers, and hosts) to "what" (content that users and applications need). CCN properties separate content name from content location, which gives built-in mobility functions by default [2]. These properties lead CCN as an attractive candidate solution for vehicular networking and be a potential key player in future vehicular communication paradigm, where it may eliminate issues related to current host-based IP addressing. This is especially true for scenarios such as high-speed trains where the number of users is significantly high and there is a need to aggregate traffic efficiency, yet provide mobile Quality of Service (mQoS) for each user.

In many-to-one connections (between many mobile hosts to an access point), different levels of service and control mechanisms would be required. These may include an intelligent control of content distribution management by defining a novel algorithm/protocol to facilitate mobile Quality of Service. Improvement towards scalable dynamic content management is potentially carried out by a new adaptive bio-algorithm for a content-centric vehicular network to improve mQoS in a large number of users. Improving mQoS performance need to address multiple qualities of content types and content streams. The content-centric vehicular network aims to enhance network resources and to reduce bandwidth consumptions on the core network. It is anticipated to bring a novel service of a low-cost content-centric network in transportation as an enhancement to the quality of service for passenger's journey.

Content-Centric for Vehicular Network (dubbed CCVN) may become a potential key player in future vehicular communication, since it may eliminate issues related to current host-based IP addressing. There is a need to aggregate traffic for efficiency in vehicular scenarios such as high-speed trains, where the number of users is significantly high as well as to ensure mobile Quality of Service for each user. The main aim of this research is to develop an architecture that will facilitate and improve mQoS for a large domain of users with fast mobility. Hence, the focus is on providing mQoS where user movement is relatively continuous during an application session. Objectives of the research may be stated as:

1. To define and design a more robust CCVN-based algorithm that utilizes some form of intelligence and/or bio-inspired for decision-making and adaptation to improve mQoS.

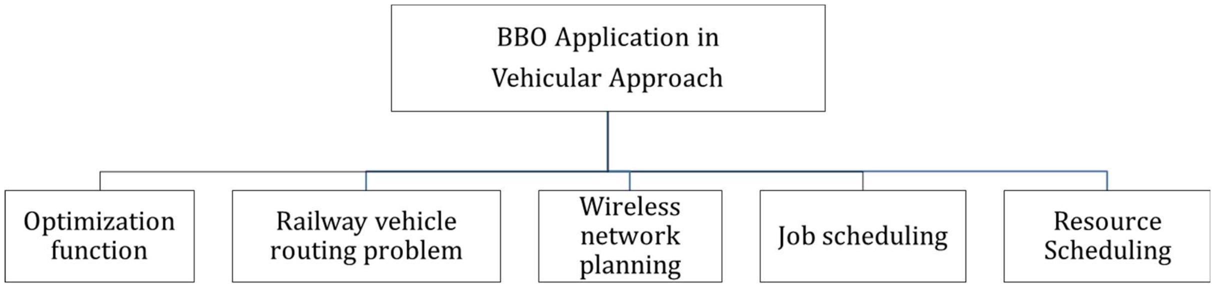

Figure 1. BBO Application in Vehicular Approach

2. To develop an adaptive or intelligent CCVN architecture for scalability & efficiency, using mathematical and/or network development tools.

3. To evaluate the proposed architecture against standard protocols and/or implementations of CCVN.

II. Literature Review

Current research efforts in dynamic content mobility can be divided into mQoS in a large number of users, mQoS in dynamic mobile users, and bio-inspired techniques in vehicular application.

A. *mQoS in a large number of users*

Maintaining a large number of users is acquired by resource assignment, allocation, and load balancing [3]. This method relies on several factors and several considerations including Bit Error Rate requirements [4]. Since n-number of users gives high variation and heterogeneity of requested packet types, an implementation strategy to find a minimum link-cost path to retrieve requested files is also considered [5]. Implementation of "smart-node" and host overload detection systems provide early QoS performance monitoring. A study in [6] concluded the direct influence of overloaded resources to QoS performances, which are system (memory and disk) overload utilization and network bandwidth. Application on the database for QoS parameters with optimization algorithm presented by Shuminoski et al [7], stores and performs a ranking function. It exhibits less complexity because of the simple output ranking function and decision output selected in mobile networks under a heterogeneous environment.

Although several works surveyed in this area aim to optimize mQoS for a group of users, current approaches raise concern in the scalability issue. This is due to the node attached by n-number of users has to maintain several requests at the same time, while its capacity is challenged by various requests and adaptability of resource allocation. The scalability issues in service heterogeneity could potentially affect QoS delivery.

B. *mQoS in dynamic mobile users*

There are several works found on maintaining QoS in mobility, focusing on the high-speed train (HST). In [8], the authors proposed three steps method consisting of threshold setting, priority assignment, and transmission rate to ensure higher QoS. In [9] authors performed virtual resource mapping between train to ground communication. Downlink service scheduling in HST by using optimal scheduling formulation and stochastic network optimization approach is investigated by [10]. Studies in [11] and [12] utilized massive Multiple Input Multiple Output (MIMO) technology and Radio Resource Management (RRM) respectively to ensure QoS requirements between the increasing demand and limited bandwidth of HSR communication.

To this date, current approaches are still lacking solutions that focus on different levels of service and control mechanisms required during user mobility. Furthermore, in fast mobile environments, extensive collaboration between network entities (onboard of a train and mobile communication network) is necessary. This implies that there is still a need to include an intelligent control of dynamic content management to facilitate mobile Quality of Service.

C. *Bio-inspired techniques in vehicular approach*

Bio-Geography Based Organization (BBO) is the study of migration, speciation, and extinction of species. Mathematical models of BBO describe how a species migrates from one island (habitat) to another, how new species arise, and how species become extinct. The BBO optimization algorithm is first presented as an example of how a natural process can be generalized to solve optimization problems [13]. BBO application in the vehicular approach has shown a promising result, as depicted in Figure 1.

In [14], enhancement of BBO algorithms has been used to resolve the vehicular routing problem on a railway. Authors in [15] reported that BBO is the most appropriate algorithm for a user for wireless network function planning. Works in [16] presented BBO to optimize scheduling tasks for computational resources, and to mitigate failure in computational resources that lead to failure of the system execution process.

III. Research Methodology

The methodology chosen for this research aims to enhance and optimize mQoS, and improve the network in railway infrastructure. The methodology design starts with a literature review where the current related and on-going work will be

surveyed. From specifically chosen literature, critical factors that influence mQoS are evaluated and considered, where it investigations into Bio-inspired optimization techniques, which are related and known for network optimization techniques to measure their feasibility. This leads to hypotheses shaping using the weighted critical factor to model proposed architecture. The known features lead to mQoS improvement and the hypotheses are further validated through simulation, implementation, and evaluation. The results obtained will then compared and/or verified with the existing solution to determine significance improvement and performance efficiency.

An important consideration in the evaluation of any kind of future Internet mechanism lies in the characteristics of that evaluation itself. Hence, the weightage factor is defined to determine the parameter matrix to calculate its cost function. The cost function for a train resource allocation is a measurement of the cost utilization to manage the resource needed to allocate passengers' content requests. It is evaluated for each cell network that is currently available and predicted to be attached to the next period. The resource allocation is needed to create a resource plan and choice of resources that would benefit passengers the most as depicted in Figure 2. The resource allocation conditions can be predicted and estimated from the known location of macro-cell towers and micro-cell towers along the trackside.

The use of Future Internet Architecture together with a bio-inspired algorithm are used for evaluation of suitable railway network conditions to enhance a mobile Quality of Service. A key component to designing an optimized algorithm is comprehensive in knowledge and understanding of influence factors and distinct parameters for which the algorithm is intended. In general, QoS is the ability of a network element (access point or a router) to provide a level of assurance for consistent network data delivery [17].

Table 1 Summary of main challenges in Railway requirements

Use Cases	Requirements Parameter	Desired Value
High Speed Train [19]	Traffic volume density	100Gbps / km in Download and 50 Gbps/km in Upload
	Experienced user throughput	50 Mbps in Download, and 25 Mbps in Upload
	Mobility	500 km/h
	Latency	10ms
Packet Delay Services for QoS Class Identifier (QCI) maintenance	Conversational Voice	100ms
	Conversational Video	150ms
	Real Time Gaming	50ms
	Non-Conversational Video (Buffered Streaming)	300ms
	TCP-Based (www, email, chat, FTP, p2p and more)	300ms

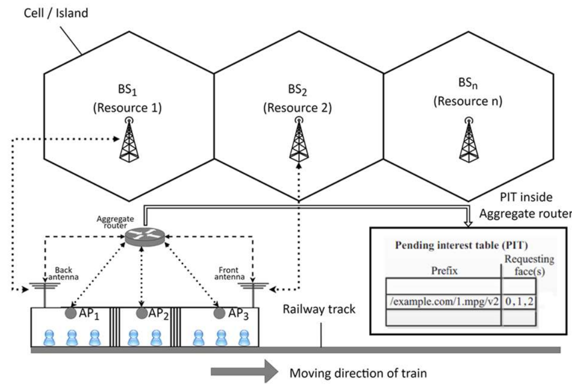

Figure 2. Implementation Scenario

Known critical parameters to achieve mQoS in the railway network, which quantitatively expressed in values (such as train's velocity, delay, jitter, available bandwidth, and packet loss) are investigated. The evaluation objective is towards the improvement and scalable dynamic content management to enhance network resources and to reduce bandwidth consumption on the core network by leveraging on micro caching technique.

IV. Results and Discussions

The expected output of this study is to deliver a mobile Quality of Service for continuous applications in fast mobile environments for aggregated traffic sources. This contribution will lead to the implementation of content-centric network architecture in a railway approach that allows the improvement of QoS performance in multiple qualities of content types and content streams. Realizing future Internet Architecture in the railway network expected to improved current IP-based architecture that operates primarily on end-to-end mechanisms. Having significant improvement in railway communication, the railway infrastructure could extend their transportation services with an enhancement to the quality of service for their passenger’s journey.

The objective of the experimental work is to investigate BBO performance in (i) a Real-time environment. (ii) Adaptive mobility, (iii) Large group of the population, compared with the well-known Genetic Algorithm (GA), and Particle Swarm Optimization (PSO). GA is chosen due to its multiple objective optimization problem. PSO is chosen for its optimal solutions, which called particles, that are flies through the problem space to reach optimum solution. Each network cost function calculated using the Analytic Hierarchy Process (AHP), [18] on a MATLAB on Windows 7 SP1; 8GB RAM; IntelCore i7 @ 3.10Ghz. AHP is chosen due to its ability to vary its weighting between each factor regarding network conditions and user preferences.

The cost function can measure the quality of each network to establish connection, and able to give merit of each available network in a fixed time, based on user preference and network condition .The average best cost functions show the algorithms’ response and computation time that is obtained at each trial. The smallest number indicates the lesser time required to finish one operating cycle in each trial..

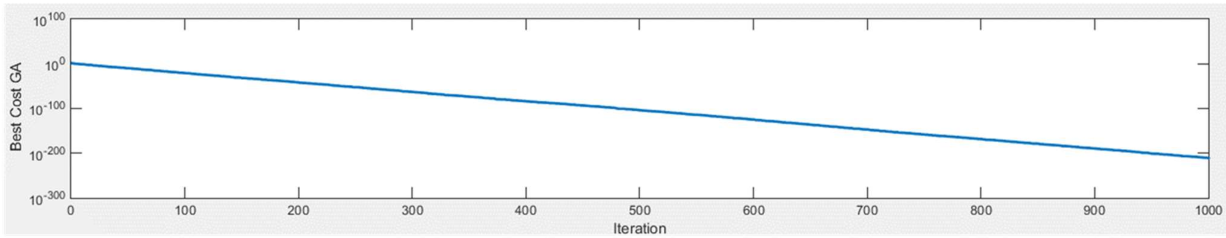

Figure 3 Best Cost Result in Genetic Algorithm

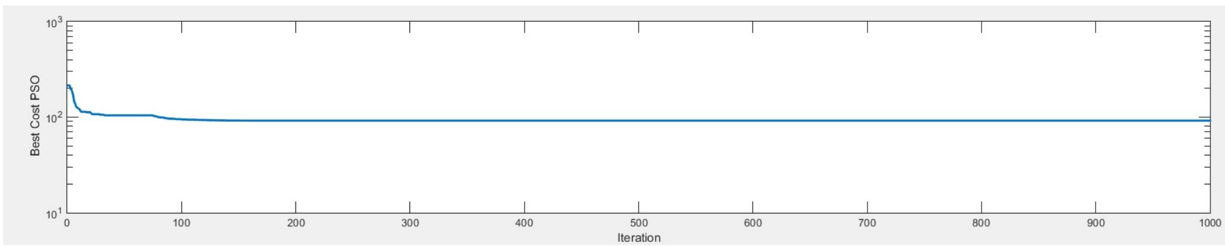

Figure 4 Best Cost Result in Particle Swarm Algorithm

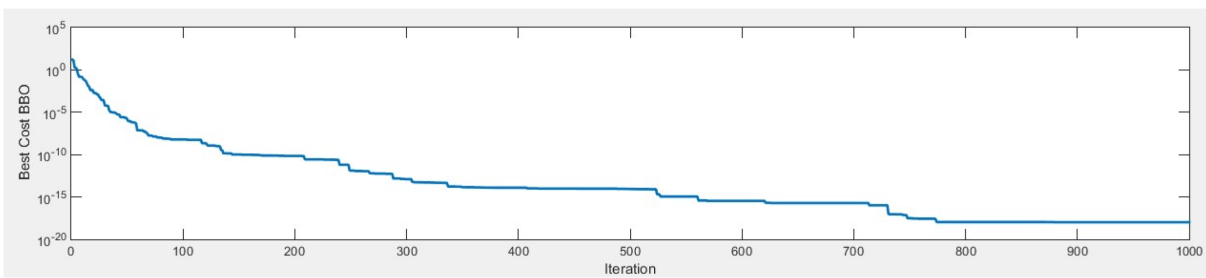

Figure 5 Best Cost Result in Bio-Geography Based Organization

The best cost of BBO shows a sharp decline of lesser time needed, then draws a steady decrease. On the overall best cost evaluation, BBO able to give a suitable cost function, suggesting better allocations based on the network condition.

V. Conclusions and Future Works

Implementing wide areas of railway communication network needs a systematic and effective mechanism to ensure that the railway networks provide continuous mobile quality of service to passengers. In implementing an effective architecture for public transportation, scalability is one of the limiting factors to ensure mQoS in a large group of mobile users. Therefore, this research hopes to significantly assure a more efficient mobile communication that accommodates massive users in fast-moving scenarios. The developments of infrastructure especially in transportation are very important to show a country's excellence growth. Quoting from Gustavo Petro; "a developed country is not a place where the poor have cars, it is where the rich use public transportation", strongly suggest continued growth in transportation development, especially for massive public use. Continuous communication, without a doubt, becomes the main daily need for the commuter. Taking these considerations, it is aimed that optimizing passenger experience across the railway network, will attract more public rail users especially on long journey trains

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