User Association with RAP for Heterogeneous Wireless Railway Networks

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Abstract: - To facilitate the journey of passengers, the modern railway system should support a wide range of on-board high- speed internet services. The Rail-track Access Points (RAPs) is an interesting idea to solve the increasing demands of passengers. These RAPs are deployed randomly along the railway line and supports high-speed data rates. RAPs are complementary to the cellular network base stations as heavy data request flushes it. In this paper, RAP association problems with the user in the heterogeneous wireless railway network are focused. Here, RAP and base station coexists in the network and to utilise the RAP services, payoff model has been introduced. We analyse the delay performance under the circumstances of totally unknown, partially known and fully known state of the system. According to the payoff model and the expected delay, the passenger decides whether to associate with the RAP or not. Performance evaluations are done on the proposed user-RAP association scheme for the heterogeneous wireless railway communication networks.

Key-words: - payoff, access points, wireless, arrival rate, mean delay time, internet.

1 Introduction

The growth of wireless communication can be seen at every corner of the world. It has become the integrated part of human's life. There has been an increasing use of personal wireless devices such as smart phones, tablets and laptops by the people whether they are sitting at their homes, at their workplace, travelling in their car, on a bus or a train. The transport industry in the past years has witnessed a high demand for internet services to provide on-board passengers with Internet access on one hand and to ensure the safety of people and trains on the other hand [1]. As in the case of high-speed trains most of the journeys takes a very long time, passengers may like to check their emails, surf a website or go for a real time multimedia streaming by accessing the internet. To provide on-board internet services, a heterogeneous network architecture can be constructed that's have a series of Railtrack Access Points (RAP). However, the RAP can only support intermittent wireless network coverage due to limited transmission power. But there exist some new challenges of train-to-ground communication caused by high mobility like doppler frequency shift and fast handover control. Rapid changes in radio channel makes wireless communication access much more arduous. Hence, it is very necessary to study railway communication networks.

According to the peculiarity of RAPs as they can only provide limited queueing buffering and data transmission rates, the delay time experienced by the passenger is one of the most delicate issue in railway communication network. Hence, complement to the base stations (BSs), RAPs are used due to heavy data traffic flushing in data delivery.

In this work, we focus on the problems of service regulations faced by any RAP connection with a queueing game theoretic approach a RAP and BS coexist together. We consider the payoff model and derived association delay time on RAPs connection behaviours, i.e., whether to join a RAP or not, are discovered. The performance evaluation is provided for the heterogeneous wireless railway communication networks to elucidate our proposed passenger-RAP association scheme.

2 Background

Many researches have been conducted on modern railway system to vantage passenger's journey. An investigation on the optimal power allocation strategy in high speed train scenario by exploring wireless communication on BSs via access points during uplink transmission is studied in [2]. In [3], the attention needed on the delay performance of the Internet multimedia streaming to satisfy passenger's demand in the heterogeneous wireless railway network is discussed. A delay analysis model is proposed in high speed train scenario by utilizing queueing theory in a discrete time but it only considers the delay performance through switch ports in carriages [4]. In recent literatures, the delay performance analysed on railway communication system about the on-demand data delivery has sometimes came out to be inaccurate results [5]. In [6], [7] end-to-end delay bound is analysed for the data applications under the heterogeneous network for one server but the cooperation between RAPs and BSs is not considered in both the works. Therefore, it is needed to focus on the delay performance in railway communication system.

During the past few decades, from an economic view, the researchers have shown their interests in queueing theory. Now it is all passenger's choice whether to associate with the queue or not, this shows that passengers are ready to wait for the service in queue or to leave the service in order to maximize their own profit [8]. Hence, a reward-cost framework is easy to construct which explicate the passenger's choice if he is agreeing to wait in the system or not. W. Zhou et al. proposes the priority auction and the uniform pricing mechanisms by considering delay sensitive customers [9]. In a Stackelberg game, by considering the server's cost mechanism the customer can make his own choice on whether to join or leave the queue. The sojourn time is the key parameter for the customers for the delay cost for the service. Z. Han et al. studies the queueing control in cognitive radio networks with random service interruptions [10]. With an optimal threshold, an individual using socially optimal strategy decides whether a data packet should associate with the queue or not. Since its channel characteristics is unknown to the system, this kind of technique cannot be used everywhere, especially in heterogeneous wireless railway network. Z. Chang et al. investigates a pricing strategy in a queueing game that a secondary user can make his own decision on whether it should join the observed queue of the base station or not based on the queue length and the reward [11]. There exist different pricing techniques like uniform pricing and priority auction [12] that can be implemented on RAP. Since it is inefficient to access the BSs for the railway networks, the much higher data transmission rates of RAP can complement the connectivity.

Motivated by the previous problems our contribution to this paper is summarized below:

1.We study a RAP heterogeneous wireless railway network model. Several rail-track side access points are widely deployed on a predefined railway line. The function of RAP is complementary to the BSs of the cellular network for providing passengers a better connectivity to the broadband services. It is assumed that passengers can decide whether to join the RAP service or to remain connected to the cellular network.

2. A symmetric game is proposed to maximize the passenger's reward which is related to the obtainable data rate and this is influenced by the delay time that they may face in the queue of the RAP. Hence, a payoff parameter is presented during the data transmission to facilitate the passenger to decide whether to associate with the RAP or not.

The reminder of the paper covers the system model of the proposed network, studies on different cases and simulating the results.

3 System Model of User-RAP Association

Here, we introduce the system model of a railway communication network using RAP. The system model is shown in the Fig.1. The RAPs are deployed along the railway track in such a manner that it gives intermittent coverage. Hence, passengers can only get connected to internet when they are in transmission range of RAPs. The packet delay is neglected here. It is assumed that the allocation of network resources based on demands is handled by central controller. Therefore, the passenger's request can enter the queue and wait till they get served.

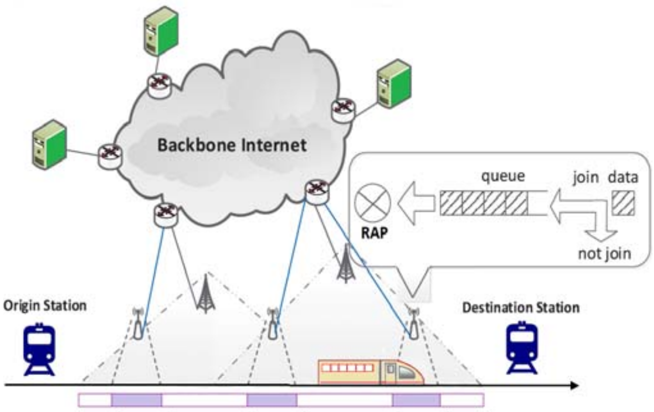

Fig. 1. *System Model*

3.1 Trajectory Movement of Train

It is assumed that the train follows a straight path and the information can be generated in advance regarding the speed and the location of the train. For analysis it is important to trace accurately the train movement trajectory. As shown in the Fig.1, the train can travel between source and destination stations in the time duration $[T_s, T_e]$. We consider a scenario in which 3 RAPs are deployed along the railway line and hence for passengers there exist three separated time durations in which they can transfer the data packets. This can be represented by $[T_s^i, T_e^i]$, $i \in [1, \dots, I]$. Here, within the ith RAP, T_s^i represents the start time and T_e^i is the end time of the delivery. Assume that $T_s^i \leq T_e^i$, $T_s \leq T_s^1$,$T_e \geq T_e^1$ for $i \in [1, \dots, I]$.

3.2 Service Process and Data Arrival Process

By considering the proposed system model, the passengers will decide for the service requests whether they want to associate with the RAP or not. If the queue of the RAP is full and no more data can be taken from the passenger, we assume that it can be transferred to the cellular base station.

The customer arrival rate λ follows the Poisson process at the RAP and across the time slots it is i.i.d. in nature. For the simplicity of model, we consider a M/M/1 queuing system with service rate μ is assumed to follow exponential distribution and i.i.d. at the RAP. Considering the heterogeneous wireless network to save the cost of deployment and to satisfy the customer's demand, in urban region more RAPs should be deployed as compare to the rural region. We assume that $T_s^{i+1} - T_e^i$ is distributed exponentially at rate ε which is the time taken by the train to cover two isolated RAPs and the serving time $T_e^i - T_s^i$ of the RAP follow exponential process at a rate ϕ. It is assumed that service order follows first come first served (FCFS) rule and also the queue information will be transferred to the next RAP when the train is not in the coverage range of the RAP.

At the time duration *t*, the state of the queue is given by a pair (*N(t), I(t)*) at the RAP, which consists the status of the train position *I(t)* and the number of customers in the system, i.e., length of the queue *N(t). I(t)* =1 when the train is in the transmission range, otherwise *I(t)*=0.

4. Queueing Analysis on User Association

The data transmission rates of RAP wireless link are much higher as compared to the base station wireless link. Hence, for customers the delay in data delivery is less in the case of RAP and it can offer better quality of service than the BS. We assume that the customer after getting served by RAP can get reward for the successful service and also the cost of a customer that he is going to pay for the service will be the function of waiting time in the queue. Hence, considering the cost and reward a customer can get, he needs to make an irrevocable decision on whether to connect with the RAP or not as the customer after association with the RAP cannot quite until being served. Since, the gap between two adjacent RAPs is very big, the customers will send create arriving requests by forming a queue before entering the covering range and will decide if they can wait in the queue until being served. This queue will get update each time a train passes the range. For the customers we introduce one more term payoff that will be the difference between cost and reward.

The customers are considered to be risk neutral and they aim to maximize their payoffs. The goal is to investigate whether customers are aware of the train's position if it falls inside the coverage range of RAP and the count of passengers waiting to be served in the queue, i.e., the queue length. We consider four cases here. Starting with the case when both *I(t)* and *N(t)* are known to the arriving passenger, then considering the case when only the length of the queue, i.e., only *N(t)* is known. We further consider the reverse condition when only the position of the train, *I(t)* is known and the case when both *I(t)* and *N(t)* are unknown.

4.1 Payoff Model

The customers of the train have the data packets to be transferred. They can obtain a reward ψ after they get served by the RAP which can be any form of benefit. For customer, we represent the cost by $\chi(T)$ where *T* is the sum of serving time and waiting time in the queue of the RAP and the $\chi(T)$ increases with *T*. Here we plead a linear example and assume that $\chi(T)$=*CT* where *C* is the value of unit cost. We assume that for *m* = 0, *K* is positive to avoid the trivial situation when *m* = 0 and *K* = 0, which leads to

$$\psi > \left(1 + \frac{\epsilon}{\phi}\right)\frac{C}{\mu} + \frac{C\epsilon}{\phi(\lambda+\phi+\epsilon)}. \tag{1}$$

For customers we can make use a generic payoff model, commonly referred as queueing analysis [13], [14].

When the train is moving, the queue information is forwarded from one RAP to the next RAP and accordingly T is derived theoretically. For a customer the payoff model is given by

$$K = \psi - CT. \tag{2}$$

This function is defined by the service time and waiting time *T*, that depends on the status of the queue and the decision of the customers regarding association with the RAP. If there is a positive payoff, the customers prefer to join the RAP but if there is a negative payoff, the customers choose not to connect with the RAP. If the payoff is 0, the customers take neutral decision. In this sense, the customers are said to be risk neutral in nature [15].

4.2 Queuing Analysis

Here the four cases will be analysed for the customers who wants to associate with the RAP.

4.2.1 Case I: When both *I(t)* and *N(t)* are known

Here, for customers arriving with the data requests both *N(t)* and *I(t)* can be generated [16]. A pure threshold strategy (PT1) is considered when the customers will be knowing the queue length and the train position, specified by the pair $(m_e(0), m_e(1))$. The customer decide according to the threshold $m_e(I(t))$ of the queue length whether to associate or not. We can define PT1 as at arriving time t, inspect *(N(t), I(t))*, and if $N(t) \leq m_e(I(t))$ then associate with RAP otherwise remain connected to cellular network by default. Hence, just before the arrival of customer, the expected waiting time is given as

$$T(m,i) = (m+1)\left(\frac{\epsilon}{\phi}+1\right)\left(\frac{1}{\mu}\right) + (1-i)\left(\frac{1}{\epsilon}\right). \quad (3)$$

Accordingly, the thresholds $(m_e(0), m_e(1))$ where PT1 is a poorly dominant strategy can be presented as

$$((m_e(0), m_e(1)) = \begin{pmatrix} \left\lfloor\frac{\psi\mu\phi - C\mu}{C(\epsilon+\phi)}\right\rfloor - 1, \\ \left\lfloor\frac{\psi\mu\phi}{C(\epsilon+\phi)}\right\rfloor - 1 \end{pmatrix}. \quad (4)$$

Based on (3), the payoff of the customer who enters the queue with state *(m, i)* is given by

$$K(m,i) = \psi - CT(m,i). \quad (5)$$

It is observed from (5) that if $K(m, i) > 0$, a customer will join with the RAP. We assume that the connection between customer and BS is occurring in a natural way and if the customer finds it beneficial they will connect to the RAP. The payoff is considered to be positive in this case. In the case when the customer decides to stay in the cellular network, the payoff is assumed to be less than 0. Hence, if $K(m, i)=0$ for *m*, the customer will connect to the RAP if and only if the total customers in the queue $m=m_e(i), \forall\epsilon\{0,1\}$ and $(m_e(0), m_e(1))$ can be found in (4).

4.2.2 Case II: When *I(t)* is unknown and *N(t)* is known

We find the equilibrium strategy when the arriving customers are unaware of *I(t)* and can only generate the information of queue length *N(t).* The threshold m_e is given by the pure threshold strategy (PT2) and is defined at the arriving time *t*, the customer is not informed about the *I(t)* but *N(t)* is known. The customer will join the RAP, if $N(t) \leq m_e$. Otherwise the customer will remain connected to the BSs if $N(t) > m_e$.

The mean delay associated in this case when the customers finds *m* customers ahead and choose to connect with the RAP can be given found as

$$\omega_1 = \frac{\lambda}{2\mu(\lambda+\phi)}\left(\mu+\epsilon+\lambda+\phi+\sqrt{(\epsilon+\lambda+\mu+\phi)^2-4\mu(\phi+\lambda)}\right),$$
$$\omega_2 = \frac{\lambda}{2\mu(\lambda+\phi)}\left(\mu+\epsilon+\lambda+\phi-\sqrt{(\epsilon+\lambda+\mu+\phi)^2-4\mu(\phi+\lambda)}\right),$$
$$\gamma_1 = \frac{(\lambda+\phi)\omega_j-\lambda}{\epsilon\omega_j}, \quad j\,\epsilon\,\{1,2\}. \quad (6)$$

Using these equations, the mean delay time can be found as

$$X_1(m) = \frac{m+1}{\mu}\left(1+\frac{\epsilon}{\phi}\right) + \left(\frac{(\omega_1/\omega_2)^{(m+1)}-1}{\phi(1+\gamma_1)(\omega_1/\omega_2)^{(m+1)}-(1+\gamma_2)}\right), \quad m\,\epsilon\,(0,1,\dots,m_e), \quad (7)$$

$$X_2(m+2) = \frac{m+2}{\mu}\left(1+\frac{\epsilon}{\phi}\right) + \left(\frac{(\mu+\epsilon(1+\gamma_1)(\omega_1/\omega_2)^{(m+1)}+(\mu+\epsilon(1+\gamma_2))}{\phi\left(\left(\mu+(\epsilon+\phi)(1+\gamma_1)\right)(\omega_1/\omega_2)^{(m+1)}-\left(\mu+(\epsilon+\phi)(1+\gamma_2)\right)\right)}\right), \quad m = m_e. \quad (8)$$

The stationary probability $p(m,i), m\epsilon\{0,1,\dots,m_e+1\}$, i $\epsilon\{0,1\}$ can be given as

$$p(m,0) = \vartheta({\omega_1}^{m+1}-{\omega_2}^{m+1}), m\epsilon\{0,1,\dots,m_e\},$$
$$p(m,1) = \vartheta(\gamma_1{\omega_1}^{m+1}-\gamma_2{\omega_2}^{m+1}), \quad m\,\epsilon\,\{0,1,\dots,m_e\},$$
$$p(m_e+1,0) = \frac{\vartheta\lambda}{\phi}\left(1+\frac{\epsilon}{\mu}(1+\gamma_1)\right)\omega_1^{m_e+1} - \left(1-\frac{\epsilon}{\mu}(1+\gamma_2)\right)\omega_2^{m_e+1}, \quad m\epsilon\{0,1,\dots,m_e\},$$

$$p(m_e+1,1) = \frac{\vartheta\lambda}{\phi}(1+\gamma_1)\omega_1^{m_e+1} - (1+\gamma_2)\omega_2^{m_e+1},$$
(9)

The stationary distribution can be obtained using the balanced equations given by [21],

$$(\phi+\lambda)p(0,0) = \epsilon\, p(0,1),$$
(10)

$$(\phi+\lambda)\, p(m,0) = \epsilon\, p(m-1,0) + \epsilon p(m,1), \quad m\,\epsilon\,\{0,1,\dots,m_e\},$$
(11)

$$\mu p(m+1,1) = \lambda\, p(m_e,0) + \lambda p(m_e,1), \quad m\,\epsilon\,\{0,1,\dots,m_e-1\},$$
(12)

$$\mu p(m_e+1,0) = \lambda\, p(m_e,0) + \epsilon\, p(m_e+1,1).$$
(13)

With (11) and *p(m,1)* and substituting in (12), we get

$$\mu(\phi+\lambda)p(m+1,0) - \lambda(\mu+\epsilon+\phi+\lambda)\, p(m,0) + \lambda^2 p(m-1,0) = 0, \quad m\,\epsilon\,\{0,1,\dots,m_e-1\}.$$
(14)

Where the solution of (14) is given by

$$p(m,0) = c_1\omega_1^m + c_2\omega_2^m,\, m\,\epsilon\,\{0,1,\dots,m_e\},$$
(15)

where the roots of the corresponding characteristic equation are $\omega_1 and\ \omega_2$. c_1 and c_2 are constant to be determined. By substituting (15) in (11), we get

$$p(m,1) = c_1\gamma_1\omega_1^m + c_2\gamma_2\omega_2^m, \quad m\,\epsilon\,\{0,1,\dots,m_e\},$$
(16)

where γ_i, i = 1,2 is given in (6). By substituting (15) and (16) into (10) and (12), respectively, the result can be obtained as $c_2/c_1 = -\gamma_2/\gamma_1$. Then the constant $c_i, \forall i \in \{1,2\}$ can be obtained using the normalised equation. We can express ϑ as

$$\vartheta = \frac{c_1}{\gamma_1}.$$
(17)

PT2 follows the nash equilibrium strategy for $m_e \in \{m_L, m_L+1, \dots, m_U\}$,where m_L is the lower limit and m_U is the upper limit of m_e which can be obtained from two sequences $r_1(m)$ and $r_2(m)$ defined as

$$r_1(m) = \phi - CX_1(m), m\,\epsilon\,\mathrm{N}^0,$$
(18)

$$r_2(m) = \phi - CX_2(m), m\,\epsilon\,\mathrm{N}^0.$$
(19)

We consider $m_L, m_U\,\epsilon\,\mathrm{N}^0$, where $m_L \le m_U$. Because of the assumption of K, $r_1(0) > 0$ and $lim_{m\to+\infty} r_1(m) = -\infty$, and if we use m_U+1 in the first non-positive of $r_1(m)$ as a subscript, one can obtain

$$r_1(0), r_1(1), r_1(2), \dots, r_1(m_U) > 0, \quad r_1(m_U+1) \le 0. \tag{20}$$

We also obtained that $r_1(m) > r_2(\mathrm{m}), \forall m \in \mathrm{N}^0$. Correspondingly, $r_2(m_U+1) < r_2(m_U+1) \le 0$. It is assumed that m_L is the first subscript that $r_2(m) \ge 0$, we have $r_2(m_L+1), r_2(m_L+2), \dots, r_2(m_U+1) < 0, r_2(m_L) \ge 0$.
(21)

We have the model where PT2 is followed by the customers for fixed value of $m_e \in \{m_L, m_L+1, \dots, m_U\}$. With the help of (6) and (7), the payoff model of the customers can be obtained. According to this payoff model when the waiting customers in the queue follows $m \le m_e$, the customer will connect to the RAP and otherwise the customer will not connect if $m > m_e$. Hence, PT2 achieves symmetric equilibrium. We propose an algorithm to generate m_L and m_U.

1. Find $r_1(m) and\ r_2(m)$ according to (18).
2. Enumerate $r_1(m)$ until the first negative term is reached.
3. The highest threshold m_U can be determined.
4. Calculate r_2(m) starting from $r_2(m_U+1)$ and reach upto 0 till the first positive term is achieved.
5. The lowest threshold m_L can be obtained .
6. Consider the obtained $m_L$and m_U.

Fig. 2. *Algorithm for finding m_L and m_U.*

4.2.3 Case III: When *N(t)* is unknown and *I(t)* is known

When an access request arrives at the queue of the RAP from the customers and they are unaware of the queue length but they know whether they are in coverage of RAP or not, Case III is considered. The mixed strategy PT2 is considered against the pure threshold strategy with the joining probability of $q(i)\epsilon\{0,1\}$, $i\epsilon\{0,1\}$. Here, $q(0)$ denotes the probability when the train is in the coverage area of cellular networks and $q(1)$ denotes the probability when train is in the RAP network coverage. Consider $\lambda_i = \lambda q(i), i\epsilon\{0,1\}$ and when all the customers who enters queue observes $I(t)$=I choose mixed strategies $(q(0), q(1))$, then the expected mean delay time can be given as

$$X(0, q(0), q(1)) = \left(\frac{\epsilon\lambda_0+\phi\lambda_1+\mu\lambda_0+\lambda_1\lambda_0}{\mu\phi-\phi\lambda_1-\epsilon\lambda_0}+1\right)\frac{\epsilon+\phi}{\phi\mu}+\frac{1}{\phi}.$$
$$X(1, q(0), q(1)) = \left(\frac{\phi\epsilon\lambda_0+\epsilon\lambda_0^2+\phi^2\lambda_1}{\mu\phi^2-\phi^2\lambda_1-\phi\epsilon\lambda_0}+1\right)\frac{\epsilon+\phi}{\phi\mu}$$
(21)

4.2.4 Case IV: When both *N(t)* and *I(t)* are unknown

When the customers could not observe the passengers in the queue and also unaware of the location of the train *I(t)* whether they are in the coverage of RAP networks or not, we assume that every customer arrives with the probability q. Therefore, the joining rate can be given by $\lambda' = q\lambda$, i.e., it follows Poisson process. Assuming that all the customers join the RAP with the same probability q and using same strategy, the expected mean delay time is

$$X(D) = \frac{\epsilon+\phi}{\phi\mu-\phi\lambda'-\epsilon\lambda'}+\frac{\epsilon\mu}{(\epsilon+\phi)(\phi\mu-\lambda'\phi-\lambda'\epsilon)}.$$
(22)

6 Numerical Results

Several simulation results are obtained on the system model to explore the effect of several parameters on the behaviour of the passengers of the train. Compared to the maximum signal to noise ratio (SNR) scenario, the proposed user association algorithm gives better results. For the Case I, it is assumed that the queue length and train position are known to the upcoming passengers. In the Fig. 3, the expected mean time is plotted with the number of customers *m* in queue. It shows that when the

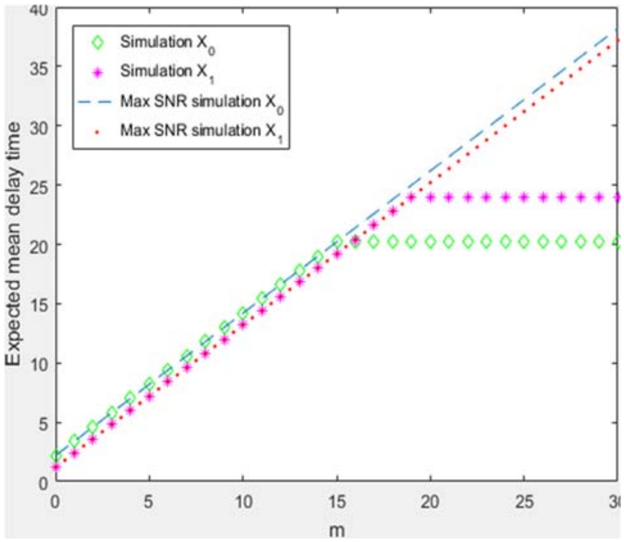

Fig. 3. *Expected mean delay time versus m for Case I when* $\mu = 5, \phi = 0.2, \epsilon = 1, \lambda = 0.5, \psi = 25, C = 1$

greater number of customers choose to wait for getting served in the queue, expected delay time

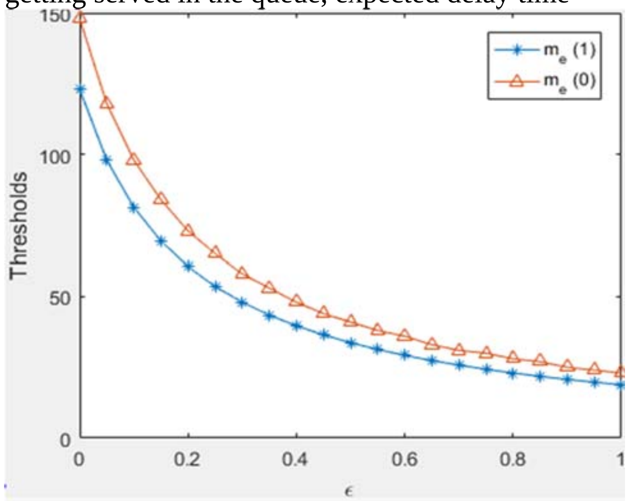

Fig. 4. *Thresholds versus* ϵ *for Case I when* $\mu = 5, \phi = 0.2, \psi = 25, C = 1, \lambda = 0.5$.

With the increase in ϵ, a greater number of data transmission fail. It can be found that the threshold is higher *I(t)*=1, i.e., when the train is travelling in the coverage network of RAP. The customers prefer to join RAP and sustains a longer queue. For the Case II when the customers with data request has no idea about the *I(t)*, then for each customer in the queue, the expected mean delay time can be observed from Fig.5. In this case the expected mean delay time is larger than the Case I.

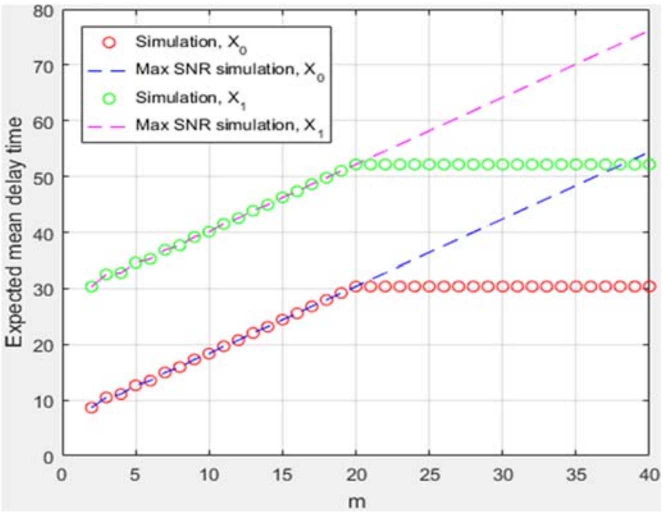

Fig. 5. *Expected mean delay time versus m for Case II for* $\mu = 5, \phi = 0.2, \epsilon = 1, \psi = 25, C = 1, \lambda = 0.5$.

By varying the value of ϵ, the thresholds of the queue length can be plotted in Fig. 6 and this can be understood that when the time duration between two isolated RAPs increases, m_L and m_U are monotonically decreasing with ϵ. The increase in ϵ shows that the travel duration will be longer between two adjacent RAPs. Hence, increase in ϵ will lead to more failure in data transmission. In Fig.7, the expected mean delay time is plotted against ϵ. Both the parameters are directly proportional to each other. Increase in the ϵ lead to the increase in the travel

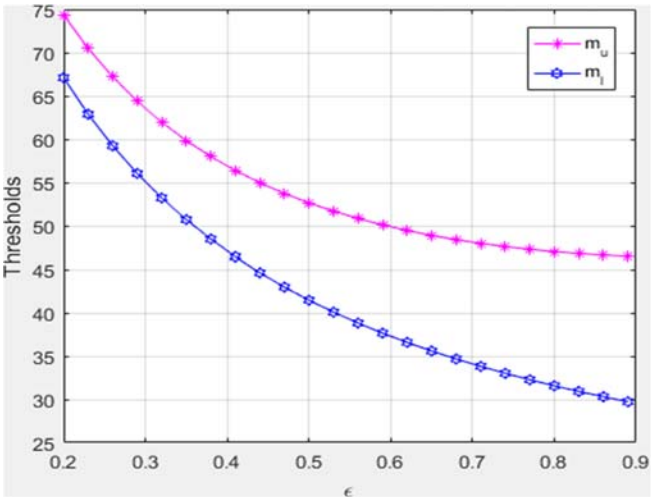

Fig. 6. *Thresholds versus* ϵ *for case I when* $\phi = 0.2, \lambda = 0.5, \psi = 25, \mu = 5, C = 1$.

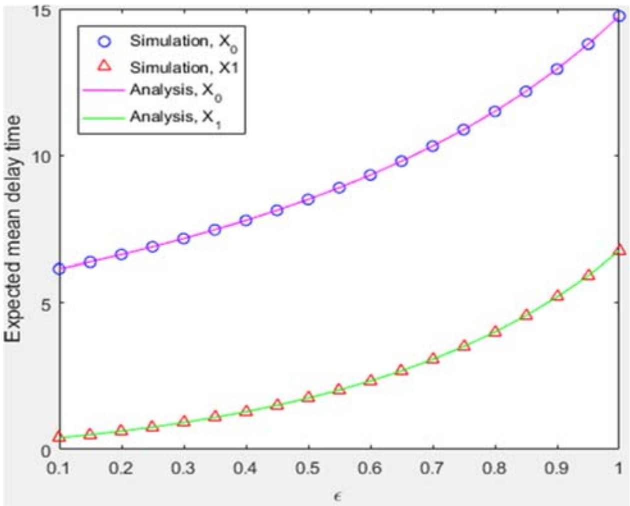

Fig. 7. *Expected mean delay time versus* ϵ *under Case III for* $\mu = 5, \lambda = 0.5, \phi = 0.2$, *C=1*, $\psi = 30$.

In Fig. 8, the expected mean delay time is presented by varying the value of ϕ. Here the serving time ϕ of a RAP becomes larger with decrese in the expected mean delay time. This is mainly due to the fact that when the TAPs are able to serve more data requests, the queue length can decrease, so as the delay time.

In Case IV, we have assumed that the both location of the train *I(t)* and queue length *N(t)* are unknown to the customers arriving in the networks of the RAP. The expected mean delay time is presented with the varying values of λ in Fig. 9. This shows that when the greater number of customers enter the queue, i.e., when the data arrival request grows, there

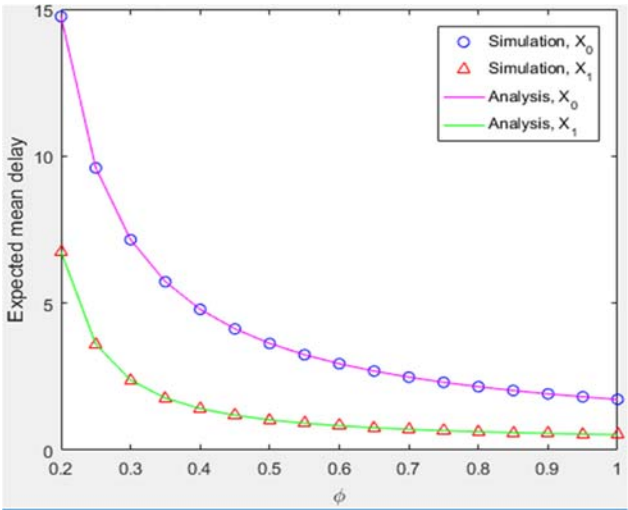

Fig. 8. *Expected mean delay time versus* ϕ *for Case III when* $\mu = 5, \lambda = 0.5, \epsilon = 1$, *C=1*, $\psi = 30$.

is an increase in the expected mean delay time. With μ the expected mean delay time decreases which means that when μ increases the RAP can serve the customers in a faster time. The expected mean delay is observed at different values of ϵ by varying ϕ in Fig. 10. The expected mean delay time decreases with increase in the ϕ. There is a dramatical decrease in the expected mean delay time when $\phi \leq 0.4$ as the customers start leaving the queue when the serving time

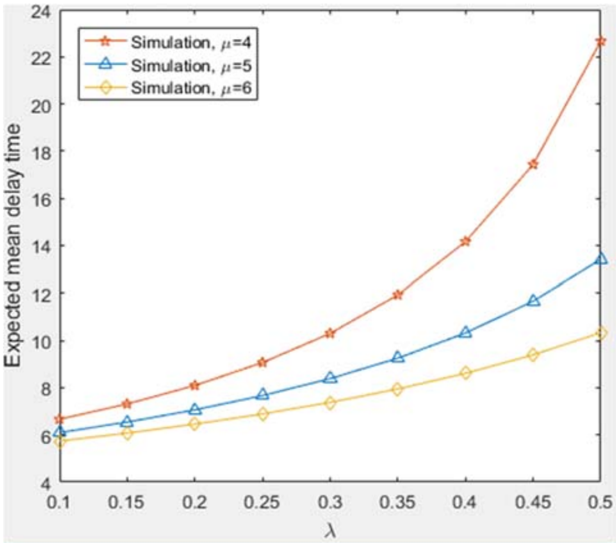

Fig. 9. *Expected mean delay time versus λ for Case IV when $\mu = 5$, $\epsilon = 1$, $\phi = 0.2$, C=1, $\psi = 30$.*

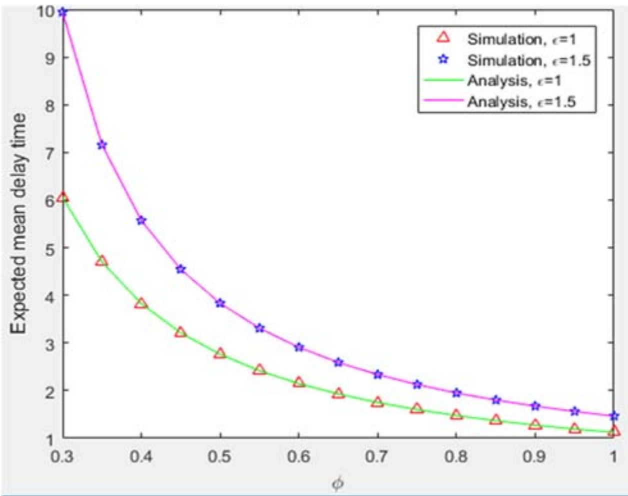

Fig. 10. *Expected mean delay time versus ϕ for Case IV when $\mu = 5$, $\lambda = 0.5$, $\phi = 0.2$, C=1, $\psi =$ 30.*

is longer. The expected mean delay is observed at different values of ε by varying ϕ in Fig. 10. The expected mean delay time decreases with increase in the ϕ. There is a dramatical decrease in the expected mean delay time when $\phi \leq 0.4$ as the customers start leaving the queue when the serving time is longer.

6 Conclusions

In this paper, a scenario of modern railway communication system is discussed where a series of Rail-track Access Points (RAPs) that are capable of providing high speed internet are deployed randomly across the railway lines. To satisfy the customer's demand, this system is adequate for providing a wide variety of on-board services. The problems faced by the customers in a heterogeneous wireless railway networks while connecting to the RAPs are analysed here. We carried out the theoretical analysis on the expected mean delay time under situations as mentioned here as: when the queue length and the state of the system are both known, partially known and totally unknown to the arriving customers of the RAP. To decide whether to join the RAP or not the Payoff model is proposed. With the help of the proposed algorithm the numerical values of the simulation results match well for the expected mean delay time.

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