Novel computational intelligence-based model for effective traffic management in intelligent transportation system

Impana Appaji[1], Raviraj Pandian[2]
[1]GSSS Institute of Engineering and Technology for Women, Visvesvaraya Technological University, Mysuru, India
[2]Department of Computer Science and Engineering, GSSS Institute of Engineering and Technology for Women Mysuru, Visvesvaraya Technological University, Belagavi, India

Article Info

ABSTRACT

The evolution of intelligent transportation system (ITS) is essentially meant for upgrading the driving experience with more safety and accessibility of various analytical information from its extensive network. However, a significant gap is observed that doesn't cater up the complete demands of ITS. It has been also noted that computational intelligence (CI) based approach is slowly gaining pace in solving the transport related problems in ITS as compared to its other counterpart existing methodologies like artificial intelligence. The proposed manuscript introduces a novel computational framework towards assisting in relaying routing and navigational services using CI-based approach. A design of novel navigational controller unit is presented for global ITS scenario towards yielding an optimal decision of routing. The CI-based approach is implemented by integrating fuzzy process with evolutionary searching, learning and probability theory in most simplified form. The study also introduces a novel concept of relaying decision as feedback from navigational controller unit to specific vehicular node discretely unlike existing traffic controller system with an agenda to offer faster and effective clearance of queued vehicular nodes from target area. The study outcome shows higher consistency in its relay with better performance from existing study model in ITS.

Corresponding Author:

Impana Appaji
GSSS Institute of Engineering and Technology for Women, Visvesvaraya Technological University
Mysuru, India
Email: impana.appaji@gmail.com

1. INTRODUCTION

Intelligent transportation system (ITS) induces modernized technologies in order to improve the process management as well as enhance the performance of transport system [1]. The prime reason of its increasing pace of adoption is due to improved mobility, supportability towards economic development, minimizing the environmental impact, and improving efficiency and safety [2]–[5]. However, it is also characterized by various impending challenges which attracts the attention of researchers. Some of the impending challenges of ITS are associated with technical complexity, data privacy and security, interoperability, higher implementation cost, public acceptance, and lack of standardization [6]–[10]. At present, there are various implementation study model being developed targeting to address the problems associated with ITS [11]–[15]; however, they are still in much nascent stage of development and is yet to witness its complete full-fledge implementation from practical perspective. The standard architecture for ITS is classified into various layers viz. physical layer, communication layer, data layer, middleware layer, and

application layer [16]. However, majority of the existing study models are considered only few of the layer-based operation and more work is required to be carried out.

A closer look into majority of the trends of existing research work showcase that relaying of the navigational services in ITS is one of the underlying operations associated towards facilitating the beneficial features of ITS. However, such form of service relaying demands heavier traffic data followed by using certain analytical scheme to perform processing of traffic data to yield better decision towards navigational services. There are certain approaches where internet-of-things (IoT) [17], internet-of-vehicles (IoV) [18], big data [19], and vehicular adhoc network (VANET) based schemes [20] has come together to offer such services towards routing. It is also noted that adoption of intelligence-based scheme is on rise towards solving complex research problem in vehicular network. Hence, the proposed study introduces a contributory framework where an intelligent-based scheme is harnessed towards facilitating an effective ITS in challenging traffic condition. The contribution of proposed study model are as follows:

− The proposed study model introduces an integrated computational framework offering seamless connectivity of vehicular network.
− A navigational controller unit is introduced in proposed scheme which considers both local and global traffic related information to undergo decision making towards traffic management.
− The study model introduces a concept of computational intelligence (CI) using simplified fuzzy logic and probability theory modelling towards undertaking decision of routing in urban traffic system.
− The intelligent navigational controller unit is capable of determining the optimal channel for clearing the queued vehicle in target area ensuring minimal waiting time in urban traffic scenario.

This section discusses about various available methodologies being implemented towards revising or upgrading the performance in ITS identified different set of research problems associated with it. Akhtar and Moridpour [21] have presented discussion of various predictive methods using artificial intelligence (AI) towards solving congestion problem in traffic. According to the study, clustering techniques are the most frequently adopted for this purpose mainly focusing on three essential methods i.e., deep learning, shallow machine learning, and probabilistic reasoning. Adoption of AI-based methodology is also witnessed in work carried out by Benterki et al. [22] that emphasizes towards analyzing the behavior of a vehicle using trajectory prediction and classification methods based on maneuvering. The study model has integrated long-short term memory (LSTM) along with neural network for this purpose. Further adoption of AI is also reported in Lytras et al. [23] where it is stated that AI schemes are most suitable for catering up dynamic demands of ITS along with using IoT-based services. Further, several researchers have presented a discussion about predictive techniques using AI toward analysis of flow of traffic and realizing the influence of autonomous vehicle on urban traffic [24], [25]. Tak et al. [26] have presented further discussion associated with detecting and tracking vehicles in ITS using deep learning. Malek et al. [27] have used deep learning scheme in order to perform prediction of speed of vehicular node. The concept used in LSTM considering both multi/univariate environment for assessing the accuracy of predictive outcome.

A unique scheme towards solving problem of allocating transport vehicle in ITS is presented by Chavhan et al. [28] using emergent intelligence scheme. This scheme processes various information related to public transport and performs scheduling and allocation of depot's agent for catering the dynamic need of commuters. Study towards problem of public transport system is also discussed in [29]. The authors attempted an investigation towards realizing the fair possibility of integration existing scheme for optimal planning of public transport system. The outcome of the study has been directed towards the need of optimization model in ITS, which is currently not witnessed in existing schemes. Eom and Kim [30] have discussed about the traffic related problems in intersection specifically associating with traffic signal. The notable outcomes of this study are; i) absence of any benchmark model for controlling traffic signal performance, ii) congestion and queue management in intersection is computationally challenging task to resolve. Study towards investigating the significance of traffic signal is also carried out by Qadri et al. [31]. Adoption of clustering towards addressing the repositioning issue of vehicle is presented in [32]. According to this study, the process of multi-tasking during sequential learning operation can be significantly improved by clustering process.

Adoption of CI towards managing wireless network using sensors are reported in [33]. The identified problem of restoration of nodes is carried out using enhanced Lagrangian relaxation model along with bioinspired algorithm using cognitive characteristic of grey wolf. There is less occurrence of pure CI-based model in ITS; however, the subsidiary and enabling technologies in it has been found to be implemented by various researcher considering vehicular network. Adoption of evolutionary computing as CI-based scheme in ITS has been discussed by Chen et al. [34] where the study outcome highlights the complexity still exists towards configure collaborative framework using edge and cloud. Husnain et al. [35] have used developed an efficient data transmission scheme using bioinspired optimization method considering the cognitive characteristic of whale for performing clustering in vehicular network. Jain et al.

[36] have integrated AI and bioinspired approach for developing a unique charging scheme for smart vehicles. Further, fuzzy logic has been witnessed towards deploying CI-based ITS. Li *et al.* [37] have developed a controller system for preventing skidding of electric vehicle using fuzzy set theory. Several researchers have also highlighted research work using fuzzy approach towards decision making for traffic system [38], [39]. Adoption of type-2 fuzzy approach is considered in work of Liu *et al.* [40] or controlling the automated driving feature. Further, adoption of fuzzy process towards rail transport system is seen in study model of Lu *et al.* [41] towards sorting out routing problem. Shi *et al.* [42] have developed a sliding mode controller using fuzzy logic for adjusting the switching operation towards acceleration control in electric vehicle. Simić *et al.* [43] have developed a model where fuzzy approach is used for overcoming the traffic problem in urban in order to dispatch the goods in conventional transport system during emergency. Adoption of fuzzy neural network is reported in work of Tang *et al.* [44] towards imputing the missing data associated with traffic flow. Apart from this, adoption of neural-network based CI approach in ITS is reported in [45]-[47]. Therefore, it is noted that there are various existing approaches of multiple variants towards addressing the problems in ITS and evolve up with a new solution. The next section highlights the associated problems with existing methodologies.

There are various beneficial aspects of existing research methodologies highlighted in prior section; however, some critical shortcomings have been noted as follow:
− The consideration of problems associated with ITS is highly specific to application or form of services. Hence, compatibility of such solution in global network of ITS is still not proven.
− The rise of AI and CI based solution is proven to be increasingly adopted by researchers; however, the prime pitfall is associated with its adoption of highly iterative mechanism and less emphasis is offered to overall ITS ecosystem.
− Majority of existing approaches are focused on adopting highly sophisticated solution in order to address the specific problem. However, such solution comes at the cost of high computational burden that is yet not validated.
− At present, there is no benchmarked study to prove any effective solution towards navigational-based relay service in ITS when considered over global ITS scenario.

Therefore, the statement of the problem is "developing a computational model for global scenario of ITS that can offer highly synchronized connectivity of vehicular network in order to facilitate dynamic analytic operation with faster response time is still a challenging task". The next section discusses the methodology adopted to solve the issues.

2. PROPOSED SYETM

The prime purpose of this part of implementation is to deploy a CI in order to improve the data dissemination performance in ITS services/application. The implementation of this scheme is carried out in analytical research methodology (Figure 1). The core target of this part of implementation is also towards accomplishing an optimization scheme which refers to minimize the dependencies from sophisticated computational effort as well as varied resources in order to accomplish higher degree of scalable performance in ITS.

Prior to briefing the architecture, it is essential to understand the problem formulation of proposed study. It should be noted that prime agenda of proposed scheme is to utilize the cost-effective CI scheme for effective navigational support towards ITS. One simpler way to do this to when the navigational controller within the vehicle is facilitated with a discrete value of traffic command signal. However, generating traffic command signal discretely for each set of waiting vehicles on different channels demands more information from the global perspective. Therefore, mathematically this problem can be formulated as (1):

$$arg_{max}[dis(t_c)] \rightarrow v(c_c)^{t_a} \qquad (1)$$

In (1) of problem formulation states that it is challenging task to maximize arg_{max} the discrete *dis* facilitation of traffic command t_c to each vehicle v present in current channel c_c for a specific target area t_a. Conventional ITS system generates common t_c for all v on specific t_a without assuming the dynamic demands of direction of journey for each vehicle. Even if this formulated problem is somehow solved, the next set of challenge will be to ensure seamless connection between two nodes, it could be vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I) or vehicle-to-anything (V2X). Without any infrastructure and considering dynamic mobility of a vehicle, the second problem in ITS for urban use-case can be formulated as (2):

$$arg_{max}(c_v) \rightarrow [v_1, v_2 | \forall t_{cc}] \qquad (2)$$

In (2), it states that it is computational higher and iterative effort task for increasing the strength and quality of communication vector c_v between two communicating nodes v_1 and v_2 in presence of obtained traffic response signal t_{cc}. The significance of this problems is an effective tcc can be only relayed of the navigational controller unit possess information about the same for its surrounding, which is unfortunately not there is existing ITS scheme. Hence combining mathematical in (1) and (2), the final problem formulation is stated as (3):

$$t_{cc} \Rightarrow \max \left[exit(v(c_c)) \right] \tag{3}$$

The inference in (3) will mean that final problem formulation of proposed system arrived is to balance the relayed traffic clearance command t_{cc} should offer maximum clearance of vehicles v in current channel over its exit points. The exit points may lead to final destination or it may eventually connect to another channel. The proposed system initiates by constructing a distributed ITS topology considering three types of inputs i.e.; i) location information of vehicle, ii) direction of vehicle, and iii) velocity of vehicle. All this information were used further for constructing an underlying graph to offer a better control of the distributed network system in ITS. The next process is towards exploring an effective position of the vehicle followed by effective path. The idea is to offer a faster clearance of the vehicles on any point in traffic system that is connected by an underlying graph for information dissemination. The study considers the presence of one hot spots in every lane segment in such a way that its transmission region encapsulates all the incoming and outgoing vehicles within that lane segment. The study also considers that all the hot spots are synchronized with each other connecting themselves with the distributed ITS topology which is hosted by cloud environment in collaborative manner. On the basis of the input obtained from vehicles, a proposed scheme also performs its decision using an objective function with CI. The outcome of the decision is then forwarded to the vehicles in the form of navigational vectors to offer faster clearance of each lane system.

The objective function using CI is designed in such a way that it should offer consistency in its decisive outcome irrespective of any situation of traffic. Following are further process carried out towards accomplishing an effective optimization performance:

− A distance-based computation is carried out for assessing the effective position and path of vehicles.
− A many-value logic system is introduced in the form of a CI unit that formulates the objective function for determining the optimal probability of road to be selected.
− The model emphasizes mainly towards minimizing the waiting period with faster clearance especially considering the use-case of intersection point where the probability of jam is either always higher or uncertain in ITS.
− All the information is forwarded to both requestor node as well non-requestor node in order to ensure better transparency in information propagation in ITS. This section further presents discussion of the strategy adopted in order to implement the proposed study model.
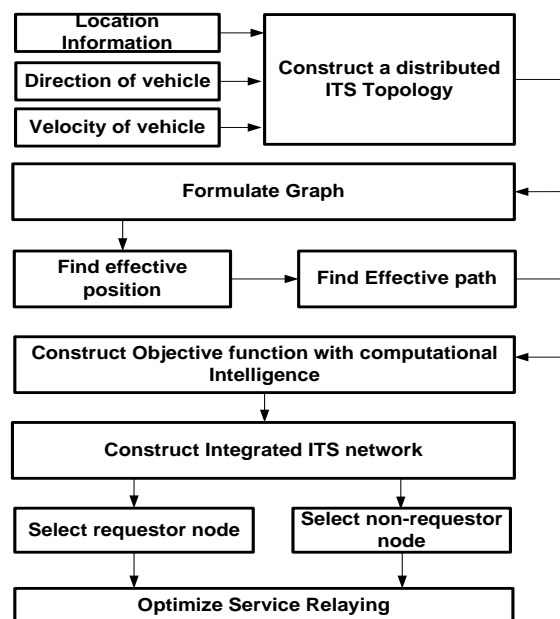

Figure 1. Architecture of proposed scheme

2.1. Exploring optimal channel

This is the first part of implementation which targets to find solution of mathematical representation of problem (1) mainly. It also indirectly solves the issue for problem formulated as (3). The problem solution is presented in the form of optimal channel exploration process. The primary strategy adopted in proposed study implementation is to explore the best possible channel. The term channels will refer to set of lanes present in considered urban vehicular network in ITS. With reference to Figure 2, this is the first implementation module where all the vehicular nodes are considered followed by a construction of a temporary matrix that retains information associated with current channel and traffic commands. The term current channel will refer to current lane segment which is under observation for analysis while the term traffic command relates to decision carried out by the centralized navigational system present in target area.
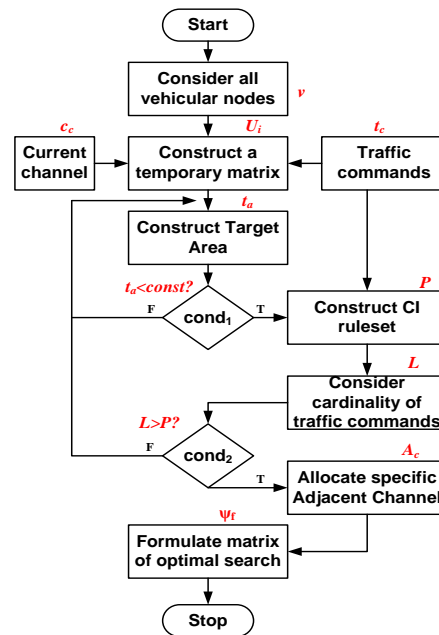

Figure 2. Mechanism for exploring optimal channel

The study considers that such controller takes the input of existing condition of traffic for current channel as well as other connected channel in global urban traffic system, performs analysis and relays the information about its decision making. This information is specific to vehicles queued in current channel. The system further constructs a target area which is basically a region where all the other neighboring channels integrate with each other. The study considers that all the decision of the navigational controller are basically relayed specifically in the target area where the vehicles are queued and awaits further input from the navigational controller to move ahead. The difference between proposed controller and existing controller scheme of urban traffic is that: proposed controller scheme performs decision of clearing the vehicle based on input from all the channels whereas existing controller system (or traffic light) yields solution only based on current channel. Another set of difference is that proposed controller offers unique directional information to vehicular node which may differ from another vehicular node even if they are on same channel. However, existing controller offers similar input of directionality of mobility of all the vehicular nodes uniformly without considering the global circumstances. Hence, proposed methodology targets for more enlarged scenario of urban traffic while existing traffic system emphasizes only on current segment of lane.

Upon constructing a target area, the proposed scheme assesses a sequential set of conditional logic to find out if the target area differs from certain constant. Further, the proposed scheme implements fuzzy ruleset as a part of CI where further evolutionary search as well as probability logic is applied towards assessing the problem space. The method further considers the cardinality of the traffic commands which can vary from one to another channel followed by assessing another conditional logic. This is meant for comparing the applicability of traffic commands with respect to CI ruleset. The term traffic command will mean a set of certain commands which are usually predefined set of instructions to be relayed by the navigational controller at the target area to specific vehicles for clearing the queue in current channel.

Further, the scheme allocates specific adjacent channel from the target area as the adopted options to clear the queued vehicles. The outcome of this optimal search is retained in specific matrix for further utilization in next stage of operation.

2.2. Relaying final traffic command

This part of implementation is associated with solving the formulated problem exhibited in (2) and (3). According to both this equation, the prime solution is furnished by the usage of non-requestor node to deal with likelihood of intermittent connection between the vehicular nodes. Not only this, but it also reduces the effort of retransmission of any request from the vehicle towards specific routes. The problem solution is also presented by formulating a temporary memory as well as matrix of optimal search from prior problem solution, which offers all the alternative possibilities of routes. The mechanism for final relay of traffic command is illustrated in Figure 3.
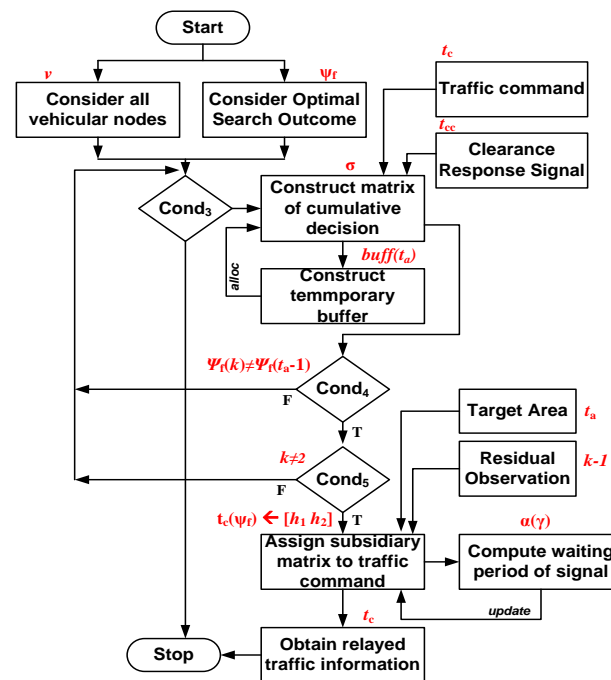

Figure 3. Mechanism for final relay of traffic command

The information within the optimal search is subjected to dynamic change when any specific traffic situation on specific channel is encountered. Upon obtaining the outcome of optimal search, this part of implementation results in further confirming the relaying of decision towards clearing the vehicles from target area. The entire operation is carried out considering two forms of nodes i.e., requestor node and non-requestor node. The requestor node is vehicular node which is seeking input from navigational controller for direction towards tentative adjacent channel. The non-requestor node is vehicular node whose assigned adjacent channel doesn't reside in current target area and they play the role of offering information about direction and node density for the navigational controller unit in urban traffic system. Using all the vehicular nodes and outcome of optimal search, this part of study model implementation formulates three discrete conditions considering both requestor and non-requestor node. A matrix for cumulative decision is formed using clearance response signal and traffic command from the navigational unit. The term clearance response signal is basically an analyzed outcome from navigational unit on the basis of various environment parameters of vehicles and channel. It should be noted that traffic commands just retain a predefined set of instruction to be relayed. The system further constructs a temporary buffer for target area followed by further conditional assessment considering residual observation in order to compute waiting period of signal. This upon updating results in finally relayed traffic information which is followed by the queued vehicles by adopting the generated adjacent channels. Further elaboration is carried out in next section in form of algorithms.

3. ALGORITHM IMPLEMENTATION

This section presents discussion about the system design in the form of an algorithm that is implemented towards accomplishing the defined objective for managing traffic system. The core objective of the implemented algorithm is to facilitate a better form of decision-making using CI in vehicular network. The complete algorithm implementation is carried out considering the common form of practical environment on every urban traffic. The prime task of the algorithm is towards selection of an optimal channel followed by reducing the bottleneck possibility in uncertain and dense vehicular nodes. The discussion of the algorithmic steps are as follows:

```
Algorithm for exploring optimal channel
Input: v, c_c, t_c
Output: ψ_f
Start
1. For i=1:v
2.      init U_i=[c_c, t_c]
3.      t_a=f(U_i)
4.      For cond_1=True
5.          P=f_1(t_a, t_uc)
6.          For j=1:L
7.              L(j)=arg_max(L)
8.              If cond_2
9.                  ψ_f←A_c
10.             End
11.         End
12.     End
13. End
End
```

The discussion of the algorithm is as following: the proposed system takes the input of v (vehicular nodes), c_c (current channel), and t_c (traffic command) which after processing yields an outcome of ψ_f (selected channel). The implementation of the proposed algorithm is essentially meant for all the vehicular nodes v and hence its algorithmic processing steps is required to consider it first (Line-1). The algorithm then formulates a temporary matrix U_i which retains information about initialized value of current channel c_c and traffic command t_c (Line-2). In the subsequent step of algorithm, an explicit function $f(x)$ is constructed which takes the input argument of newly generated temporary matrix U_i (Line-3) in order to generate a target area t_a. It should be noted that complete algorithm works on an evaluation based on the input obtained by the system and hence there is also a possibility of lag in arriving to this outcome of computation of t_a due to nature of wireless network and uncertain mobility of the vehicular node v. However, the variable current channel as well as variable traffic command is considered to be static for certain cut-off duration of time on a specific channel and this is the reason that adoption of these two variables (c_c, t_c) will not have much impact of dynamicity on the current computation of t_a. Further, it should be noted that there are possibilities of multiple number of target area ta at the end of each channel; therefore, the proposed scheme simplifies the computation by considering an arbitrary number of vehicular nodes passing through specific target area t_a. The consecutive step of the algorithm considers assessing a primary conditional logic $cond_1$ which evaluates if the number of target area t_a is less than certain reference value of it (Line-4). The reference value is density of vehicular node present in specific channel approaching the target area t_a. For an example, consider the n_d is node density in channel-1 approaching target area, therefore, according to this condition $cond_1$, the evaluation carried out is as (4):

$$t_a > \text{constant}. \, n_d \tag{4}$$

It is quite obvious that number of ta on specific channel should be always less than n_d; however, it could possibly fluctuate between quite lower and saturated value of n_d. In such circumstances, the target area is either required to offer lower priority to its n_d in its respective channel ($t_a \gg n_d$) or else it is required to offer higher priority ($t_a < n_d$). The value of constant is residing between [0 1] of probabilistic model. If the number of target area t_a is found to be less than reference value than it signifies the state of bottleneck situation which is sorted out by introducing another explicit function $f_1(x)$ (Line-5). It will also mean that if conditional logic $cond_1$ is found to be true (Line-4) than the traffic system is required to prioritize the specific channel connected with the target area t_a. This process of clearing is carried out by transmitting specific form of traffic command t_c by further updating it to obtained updated traffic command t_{uc} to specific t_a (Line-5). The prime role of the newly formulated function $f_1(x)$ is to perform a computation of specific decision controlling the clearance of the vehicular nodes queued in target area t_a. This mechanism of clearance of the vehicular nodes is carried by considering the updated information of traffic command t_{uc} from other channels too to

formulate better global decision making. This process is carried out by setting up fuzzy rules using $f_1(x)$ which are stored in matrix P (Line-5). Further, the proposed scheme considers the variable L as the adjacent channel connected to the target area t_a as the candidate solution (Line-6). Hence, better decision making is only possible when the proposed scheme considers the maximum arguments of adjacent channels L (Line-7).

Further, the proposed scheme constructs secondary conditional logic $cond_2$ where it assesses if the value of adjacent channels L is more than that of fuzzy ruleset P (Line-8). This condition will mean that formulated fuzzy ruleset P is successful in confirming the best channel out of all the available adjacent channel L from its specific target area t_a. It should be further noted that the variable L consists of various set of traffic commands t_c that is responsible for controlling the clearance of the specific vehicles queued in specific channel. All this information is stored in a buffer of adjacent channel i.e., A_c which is that allocated to final outcome of selected channel ψ_f (Line-9). Therefore, this algorithm represents a most simplified mechanism of deploying CI in order to confirm a decision of optimal search of channel in urban traffic system.

The next part of the algorithm implementation is the continuation of the prior algorithm that confirms the presence of optimal channel. This algorithm is more emphasized towards offering more reliability in case of dynamic event of present in an urban traffic system. A closer look at the prior implemented algorithm will show that it is focused on accomplishing local optimality considering current channel while the second algorithm is now focused on accomplishing equivalent state of optimality for global channel system. The idea is to offer better sustainability as well as consistency in processing of the algorithms as well as ensuring a formation of a well-connected and highly organized network of urban traffic system. The algorithmic steps are as follows:

```
Algorithm for final relayed traffic command
Input: v (vehicular nodes), ψf (Selected channel)
Output: tc (relayed traffic command)
Start
1. For i=1: v
2.     For j=1: ψf
3.         If c ond3=True
4.             Construct σ=[tc, tcc, ψf]
5.             σ(i, j)←buf(ta)
6.              If cond4=True
7.                 If Cond5=True
8.                     tc(ψf) ← [h1  h2]
9.                     compute α(γ)
10.                    tc(ψf) ← [h1  h2]
11.                End
12.             End
13.         End
14.     End
15. End
End
```

The discussion of the algorithm is as follows: the proposed algorithm takes the input values of v (vehicular nodes) and ψ_f (Selected channel), which after processing yields an outcome of t_c (relayed traffic command). In order to keep the updated information of any form of an incoming vehicle on specific channel, it is essential for this algorithm to consider vehicular nodes v as the primary input (Line-1). Further, the outcome obtained from prior algorithm i.e., selected channel ψ_f is further considered to narrow down the search towards the optimality state of navigation for each vehicular node (Line-2). For simplification of the computation in proposed scheme, the algorithm is required to initialize practical values of target area t_a. The range of values that can be allocated for t_a is $2 > t_a > 4$ considering the normal scenario of any urban traffic system. In the subsequent steps of operation, the algorithm performs a conditional check $cond_3$ where the system assesses if the value of clearance response signal t_{cc} is more than the reference score of clearance λ. This condition will practically imply the higher possibility of clearing a greater number of queued vehicles in target area t_a. Upon confirming the true case of this condition $cond_3$ (Line-3), the proposed algorithm constructs a matrix σ which consists of prior traffic command t_c, clearance response signal t_{cc}, and selected channel ψ_f (Line-4). The prime reason for undertaking this step of algorithm are as follows: i) adoption of prior traffic command t_c assists in evaluating the success rate of prior response from signal for specific target area t_a, ii) adoption of clearance response signal t_{cc} assists in clarifying the total number of vehicles being permitted to exit from the queued channel, while iii) adoption of selected channel ψ_f assists in offering a candidate channel to be considered for cleared vehicles to move. This operation is carried out by constructing a temporary buffer buff considering the input argument of target area t_a that is further assigned to matrix of cumulative decision i.e., σ (Line-5). This step of operation will eventually mean that the proposed search area towards optimal solution is retained in a temporary buffer where further decision is carried out in faster and

more reliable way. In the subsequent process, the proposed algorithm constructs another conditional logic $cond_4$ which assesses the degree of equivalency for; i) selected channel ψ_f with respect to k-number of observations of channel and, ii) selected channel ψ_f with respect to other target area t_a (Line-6). If the assessment doesn't find any form of equivalency than it further formulates another conditional logic $cond_5$ to checks k≠2 which will mean that number of observations for individual channel should be greater than minimum 2 adjacent channel atleast for acquiring more information of residual target area t_a and channels associated with it for better decision making (Line-7). If the above-mentioned condition $cond_5$ is found to be true than the algorithm constructs two subsidiary matrices of selected channel as h_1 and h_2 and allocated them to matrix of traffic command t_c with respect to prior selected channel ψ_f for upgrading (Line-8). According to this concept, the proposed scheme configures the score of tc corresponding to $(k-1)$ as h_1 while the score of the t_c corresponding to k round is assigned h_2. For simplification, the proposed scheme considers $h_1=0.5$ and $h_2=0$. Further, the algorithm computes duration of queue in current traffic γ with respect to the clock time α associated with each vehicular node (Line-9). Further, the update operation is carried out for relaying the traffic command t_c on the basis of current node density n_d (Line-10). The difference in Line-8 and Line-10 is that i) execution of Line-8 calls for constructing a traffic command on the basis of k-observation and target area t_a while ii) execution of Line-10 calls for only current and other target area t_a. This completes the overall algorithmic processing where the final outcome of relayed traffic command is obtained in last step (Line-10).

A closer look at the contribution of both the connected algorithms are as follows: i) the algorithm has less iteration and more inclusion of progressive steps resulting in faster execution with reduced computational burden, ii) both the algorithm tends to perform computation using updated traffic information without saturating the existing memory owing to usage of more temporary buffers, whose values are disposed off once utilized. The next section discusses about the accomplished outcomes of above algorithm implementation.

4.   RESULTS AND DISCUSSION

From the prior section, it is noted that proposed scheme is mainly associated with implementing a novel and simplified CI-based framework in order to perform optimal traffic management. Hence, the evaluation is carried out by developing an initial ITS simulation framework with presence of various attributes e.g., vehicular nodes, hotspots, navigational controller unit, channels and its connected adjacent channels, traffic command related from navigational controller unit, and target area. The adopted simulation parameters are highlighted in Table 1.

Table 1. Simulation environment

Parameter	Value
Total vehicular node	800
Capacity of one channel	50
Throughput	300 Mbps
Vehicle wireless standard	IEEE 802.11
Number of adjoining channels in target area	4
Total iteration	1000
Simulation Area	1200 x 1200 m^2
Traffic type	Urban

Different from existing assessment of vehicular network using map-based approaches in urban traffic system, the framework of the proposed scheme performs on-the spot computation in respective target area, uses computation intelligence followed by generation of traffic command for clearing the vehicles in target area by navigational controller unit. Multiple unconventional performance metric has been used owing to the novelty of the proposed study model. The core idea of this assessment is to understand the effectiveness of relaying traffic command for clearing maximum number of vehicles in channels.

The simulation visuals are shown in Figure 4 for one specific case study towards single target area which is represented by one intersection point of a road in ITS. The simulation outcomes show number of vehicles for each specific lanes that are either forwarded with waiting signal or forwarding a clearance signal. The unique observation is that irrespective of the presence of many numbers of vehicles, the navigational controller selects specific and discrete number of vehicles in each channel to be cleared unlike existing traffic management where all the vehicles are cleared. Hence, this is a significant novelty introduced by proposed scheme which identifies the demands of vehicles on the basis of waiting time and then undertakes the decision of either letting them to wait or to move.

Figure 5 showcase the original simulation outcome with respect to response consistency in Figure 5(a), time for feedback relaying in Figure 5(b), duration of traffic command in Figure 5(c), and counter of clearance and number of vehicles cleared in Figure 5(d). From the direct outcome, it can be stated that all the performance parameters are to exhibit a better uniformity with respect to test case of 4 channels under assessment environment. Although, the outcome has been obtained instantaneously for a single target area, it is observed that irrespective of any time of vehicle journey in dynamic scenario of ITS, the navigational controller always maintains similar form of consistency in its traffic management. The next section further elaborates these 4 performance parameters and offers collaborate inference of results obtained in global environment.
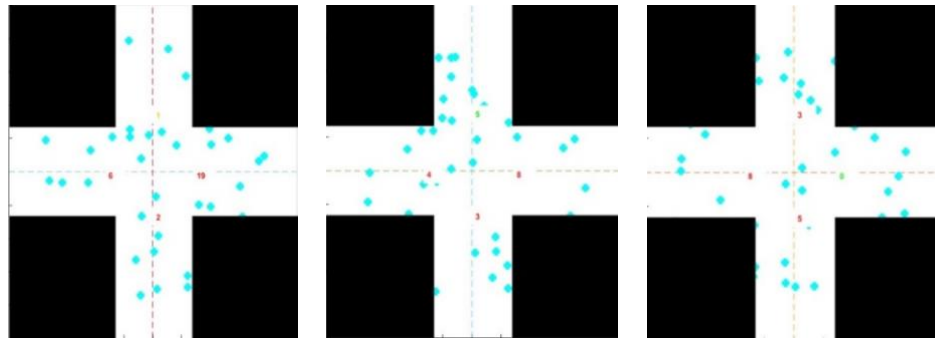

Figure 4. Visuals of Simulation in one single intersection of road (target area)
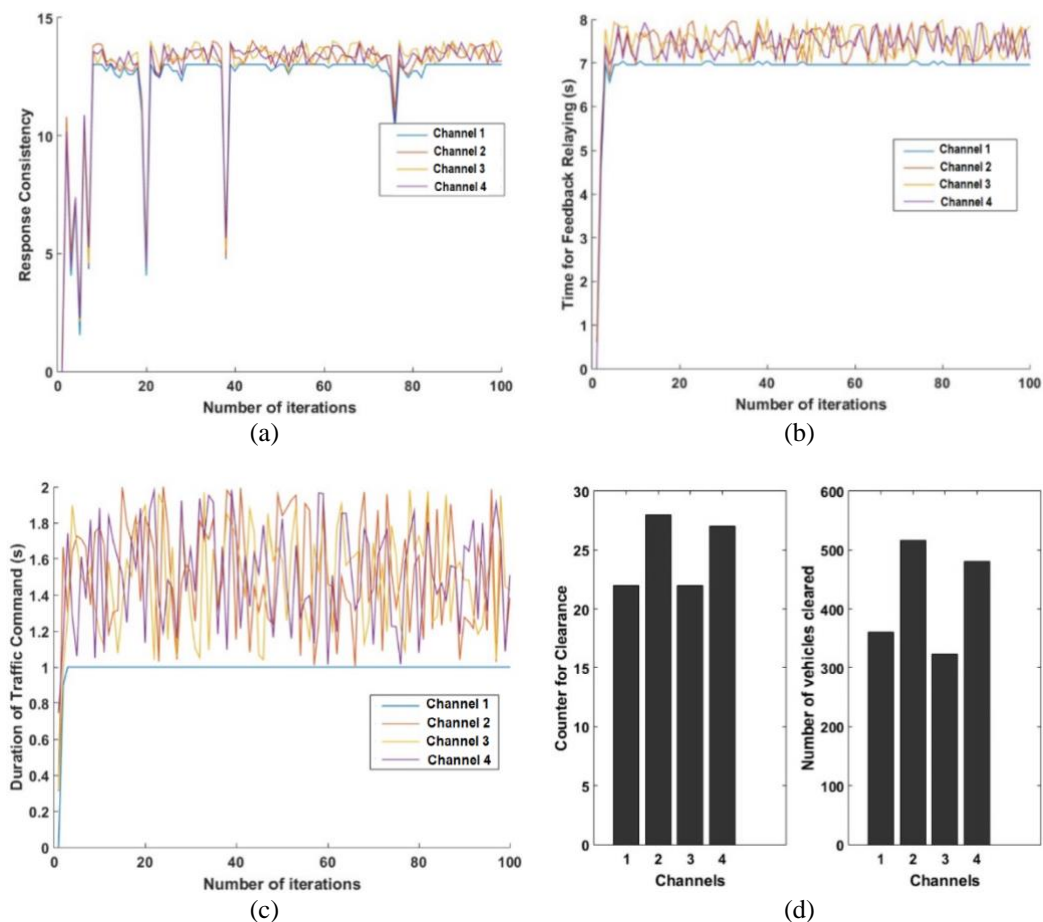

(a)

(b)

(c)

(d)

Figure 5. Graphical results of simulation for (a) response consistency, (b) time for feedback relaying, (c) duration of traffic command and, (d) counter of clearance and number of vehicles cleared

4.1. Assessment of response consistency

The term response consistency will mean the proportion of the vehicular nodes being managed by 4 test channels under observation without exhibiting fluctuation inspite of variable navigational demands requested by each vehicular node. The observation is carried out on 4 sets of iterations (iteration-1: 250, iteration-2:500, iteration-3:750, and iteration-4:1000). The rationale behind adopting this performance metric is to understand the capability of handling vehicular clearance system by navigational controller unit on respective channels. Higher fluctuating over increased iteration will only mean less coordinated navigational unit while less fluctuating number of vehicles on each channel will represent highly synchronized navigational controller unit.

The outcome exhibited in Figure 6 showcase that channel-1 with a less node density maintains the range of 10-11 vehicular nodes over increasing iteration. Similarly, channel-2, channel-3, and channel -4 are found to maintain a range of 10-14, 12-13, and 10-14 vehicular nodes respectively over increased iteration. The overall difference in proportion of fluctuation in vehicular nodes are only 1.5%. Therefore, the graphical outcome states that proposed scheme can offer better consistency of response of traffic command to different vehicular nodes residing on different channels with different node density. Hence, better exhibit of system performance consistency can be observed.
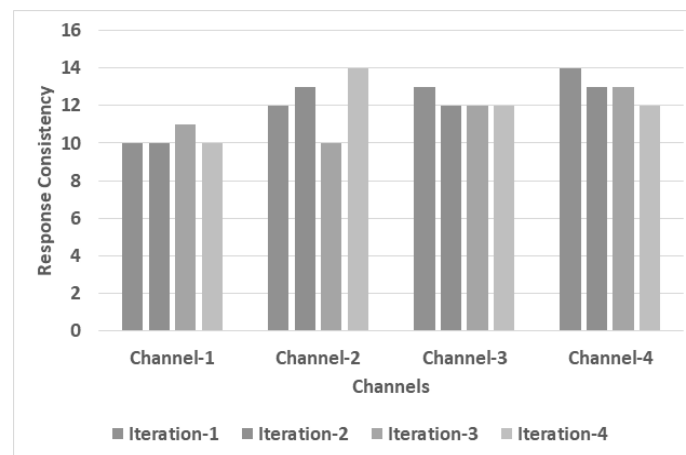

Figure 6. Assessment response consistency

4.2. Assessment of time for feedback relaying

The performance parameter time for feedback relaying represents overall time required by the navigational controller unit to relay the decision of navigational feedback (requested by the vehicular node) on each individual channels under observation. The reason for adopting this performance metric is to evaluate the difference of time consumed for relaying computed traffic command to different requestor node in different channels with varied traffic characteristic. The system can be called as efficient only if; i) there is lesser time consumption for relaying the feedback of traffic command, and ii) there are nearly equivalent trend of these time attributed over all the channels in ITS.

The outcome in Figure 7 shows that time spent for relayed the feedback for channel-1, channel-2, channel-3, and channel-4 are in range of 7-9 seconds, 6-8 seconds, 6-8 seconds, and 7-8 seconds respectively. This outcome offers two inferences viz; i) the mean difference in time required for feedback relaying for all the channels under observation is approximately 1.75%, which represent a satisfactory consistency in relaying performance, and ii) overall 2 seconds of maximum difference is found for increased iteration for a single channel. This outcome states that proposed CI-based navigational controller unit can judge equally all the request from varied sources and yet consumed less processing time to relay the actual feedback to different vehicles in ITS. This outcome is also in supportability of higher synchronization of varied services in ITS with faster feedback.

4.3. Assessment of duration of traffic command

The term duration of traffic command represents the duration of activeness for relayed traffic command towards requested vehicles on each channel under observation. The conventional traffic commands are only three viz. red light, green light, and yellow light; however, it is quite inevitable that futuristic

ITS-based services will call for introducing multiple form of pre-defined traffic commands which could be either more or less than conventional traffic commands. Similar to conventional traffic command, the proposed scheme also offers a standard time of activeness of relayed traffic command. Upon expiration of this current traffic command duration, the next computed traffic command takes the place of prior one to be relayed. However, this duration of traffic command cannot be same for all the channel at single point of time. Owing to variable traffic condition, such duration will also vary. Hence, the worst possibility with sub-optimal outcome will arise if there is heavy fluctuating duration of activeness of traffic command in different channels at same time. While better optimal solution can be ensured if all the channels experience nearly same duration of activeness of this traffic command. Hence, the motive of this performance metric is to assess the variation observed in duration of traffic command in each channel under observation.

From the outcome in Figure 8, it is noted that channel-1 witness's duration of 0.7-1 seconds, while Channel-2 witnesses a duration f 1.6-1.8 seconds. Further, channel-3 and channel-4 witnesses a duration of 1.5-1.9 seconds and 1.5-1.8 seconds. A closer look into all the trends shows that overall variation among all the 4 channels is approximately 4% while the minimum and maximum duration observed is between 0.7-1.8 seconds. This score justifies a very reduced duration of one active traffic command, which also infers following: i) proposed scheme always maintain a significantly variable duration of active traffic command in each channels but not exceeding more than 4 seconds even when the iteration is increased to maximum, and ii) there is a faster switching mechanism for all the traffic commands exhibited by this lower duration score representing proposed scheme does equivalent justification for non-requestor node too along with requestor node in priority. Hence, it will eventually mean that proposed scheme processes the query of requestor by navigational controller unit very discretely without affecting the interest of navigation for non-requestor node in specific channel.
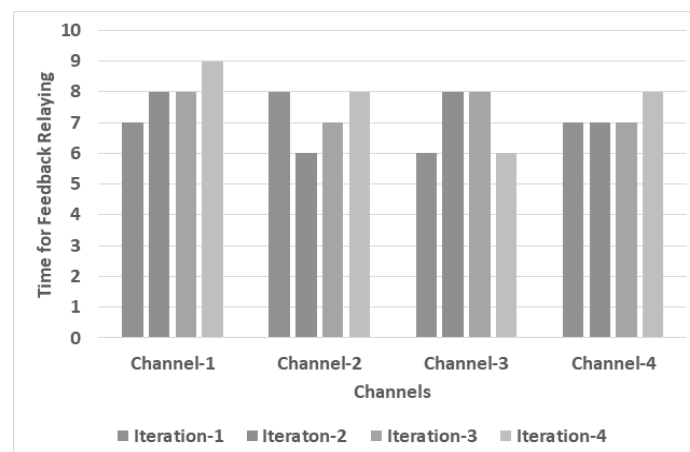

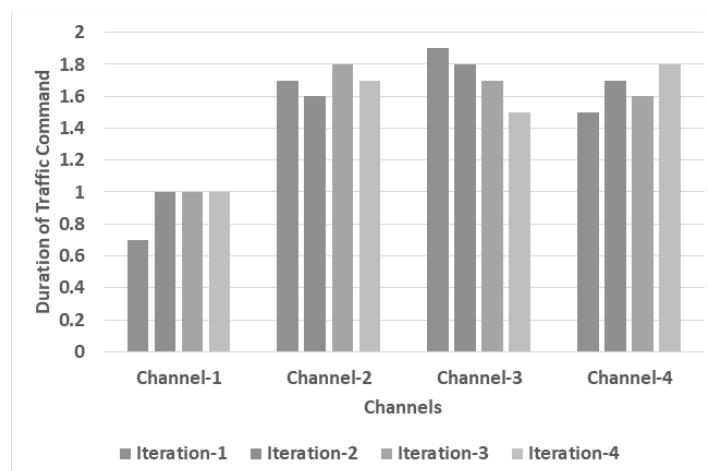Figure 7. Assessment of time for feedback relaying

Figure 8. Assessment of duration of traffic command

4.4. Assessment of duration of traffic command

The term vehicle clearance system as a performance metric represent two attributes mainly i.e.: i) counter for clearance, and ii) number of vehicles being cleared. The first attribute counter of clearance will represent total number of clearances as a traffic command exhibited in one set of iteration (i.e., 250 rounds) by the navigational controller unit at same point of time. The second attribute number of vehicle will represent total number of requestor node being cleared upon receiving the clearance feedback from navigational controller unit out. The core idea of this performance attribute is to assess the effectiveness of clearing the queued vehicles from each target area. The assessment of vehicle clearance system is illustrated in Figure 9.

Figures 9(a) and 9(b) represents the outcome of counter for clearance and number of vehicles being cleared. The outcome shows that channel-1, channel-2, channel-3, and channel-4 has witnessed 36, 44, 34, and 39 number of traffic commands for clearing the queued vehicles at same point of time (Figure 9(a)). Further, at the end of observation round, it is noted that channel-1, channel-2, channel-3, and channel-4 has cleared 440, 700, 500, and 720 vehicles successfully. This part of analysis was carried out with small number of vehicles first (v=100) , which was later exponentially increased by increasing the capacity of channels by introducing a greater number of connecting channels. The idea is to assess the performance of the overall system when exposed to a large channel of networks in ITS. The outcome exhibits that proposed navigational controller unit is quite efficient in processing the query and give final feedback for clearance without much fluctuation representing a good synchronous links among all navigational controller units. Hence, one the basis of this outcome, it can be stated that proposed scheme is capable of identifying and realizing the traffic condition for large scenario, perform distributed computation, and generates the feedback of traffic command on the basis of node density, and number of queued vehicles.
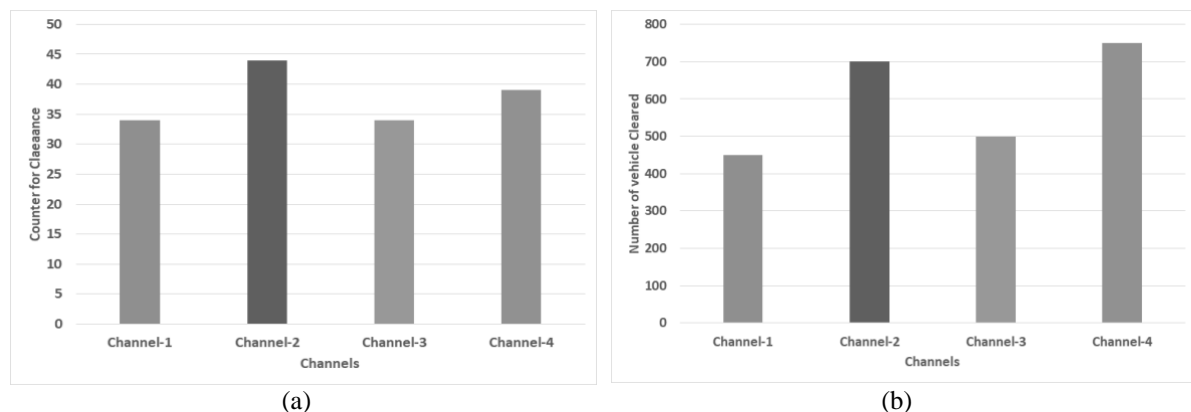

(a)   (b)

Figure 9. Assessment of vehicle clearance system for (a) counter for clearance and (b) number of vehicles cleared

Apart from the discussed study outcomes, the outcome of the proposed scheme is further compared with the state-of-the art methods. Table 2 highlights the outcomes which states that proposed scheme eventually has a beneficial aspect in contrast to different variants of approaches towards improving ITS. One of the important aspects to understand here is that almost all the existing approaches have considered various set of problems associated with ITS where the solution obtained are claimed to be optimal. However, when the same existing framework is considered for global ITS scenario, there are highlights of various pitfalls. The prime reason is adoption of methodology and structuring them towards addressing the specific set of problem which doesn't include complete ITS scenario. It is to be noted that a complete ITS scenario must involve seamless connectivity and coverage with all the involved entities.

Therefore, from Table 2, it can be noticed that existing AI-based schemes are mainly associated with higher computational complexity due to their highly iterative operation as well as higher dependencies to resources. Hence, such AI-based existing methodologies may suit well for non-emergency applications in ITS but not for dynamic and tie-critical application in ITS. The existing analytical learning model has better benefits compared to AI till now as they can be successfully proven to be used in scheduling and route planning which is one essential requirement in ITS in order to cater up many applications in ITS. However, they are too specific of services and cannot be deployed on overall ITS scenario. The CI-based scheme is still in starting level of implementation. Although some positive outcomes have been recorded using evolutionary

approach, fuzzy approach, and neural network approach, but its shares nearly the similar pitfalls like that of existing approaches using AI. On the other hand, proposed scheme introduces a very simplified, non-iterative, and highly progressive computational framework which considers complete ITS scenario. It is capable of performing analytical operation on the basis of all connected navigational controller unit. Further, it is capable of relaying the unique computed feedback outcomes for clearing the vehicles uniquely unlike any conventional traffic model. Apart from this, there is a higher degree of consistency of outcomes observed in proposed model when exposed to low to peak traffic condition. Apart from this, it is to be noted that an effective traffic management can be also carried out by using artificial based approach which can facilitate power of CI to extract all hidden traits of the problem. Appaji and Raviraj,[48] have used deep neural network for facilitating better form of vehicle communication system and it's proven to offer low resource consumption, low computational burden, and higher overall efficiency. Hence, the proposed model can be a complimentary optimization scheme further on our prior model towards better traffic management.

Table 2. Comparison with state of art methods

Approaches	Computational complexity	Benefits	Limitation
AI [21]–[23], [26], [27]	High	Higher accuracy	− Solution not applicable for global ITS − Highly Iterative − Accuracy depends on trained dataset − Not resource efficient
Analytical learning method [28]–[32]	Medium-high	− Effective traffic scheduling − Effective planning of routes − Simplified clustering	− Determination of optimal solution still not applicable for complete ITS − Service specific solution
CI Evolutionary- [34]–[36] Fuzzy- [37], [41]–[44] Neural network- [45]–[47]	High	− Capable of solving multiple problem − Effective in modelling higher dimension of transport system − Can be used for both hardware and software-based approach − Capable of modelling complex problem	− Non-considering of complete ITS ecosystem − Sub-optimal outcome due to lack of constraint consideration
Proposed	Low-medium	− Considers complete ITS scenario − Solves routing and analytical problems − Maintain consistency in output in variable traffic condition − Novel feedback relay system specific to vehicles	Applicable only on urban traffic system

5.   CONCLUSION

The current study model has introduced a novel and simplified computational framework which is capable of offering a faster and reliable navigational and routing services in ITS. Following are the novelty of the proposed scheme: i) the proposed scheme introduce a navigational controller unit which offers decision feedback of routing specifically for a discrete requestor vehicular node, ii) the complete analysis of the decision feedback of routing is carried out by considering the global scenario of channels in ITS unlike existing scheme which only considers the local routes, iii) the complete process is designed using CI-based scheme which doesn't include excessive iterative operation and is highly progressive in its operation, iv) the most significant novelty of this model is that it is capable of offering the different decision feedback of routing to different vehicular nodes maintaining higher level of consistency for all the channels. The future work can be carried out further to optimize the search towards bottleneck points in traffic channels.

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BIOGRAPHIES OF AUTHORS

Impana Appaji holds an M.Tech. in Software Engineering, post-graduation from SJCE Mysuru, affiliated to Visvesvaraya Technological University, Belagavi, and Karnataka, India in 2014. She also received B.E. Degree in Computer Science from GSSSIETW, Mysuru, and affiliated to Visvesvaraya Technological University, Belagavi, Karnataka, India in 2009. She has 13 years of teaching experience. She is currently working as senior analyst at infosys. She has published 12 research papers in international journals and conferences from 2009 to 2023. She can be contacted at email: impana.appaji@gmail.com.

Raviraj Pandian completed his doctorate degree in computer science and engineering in the area of image processing. He holds a position of professor & head in the Department of Computer Science & Engineering, GSSS Institute of Engineering & Technology for Women, Mysore. Additionally, he also serves as an IQAC-Director at GSSS Institute of Engineering & Technology for Women, Mysore. He has 16 years of teaching and research experience. He has published more than 90 papers in international journals and conferences and 8 book chapters. He serves as an editorial board member and reviewer for more than 15 international journals. He is also a life member of professional bodies like ISTE, CSI etc. He has guided the Ph.D. research scholars in the areas of image processing, pervasive & cloud computing, bio-inspired algorithms, and robotics. He has received the project grant Rs.5 Lakhs from the VGST, Govt. of Karnataka for the "underwater robotic fish for surveillance and pollution monitoring". He has served as a chair person and keynote speakers of many national and international conferences. He has been served as a board of studies member, subject expert, Ph.D. thesis evaluator for the various universities and autonomous institutions. He has reviewed lot of articles in international conference proceedings and journals. He has been received various awards such as 'Rhastriya Gaurav Award-2015', 'Shri P.K. das Memorial Best Faculty Award-2012', 'Young Achiever Award-2016', 'Best Circuit Faculty Finalist Award-2017' for his outstanding academic achievements and contributions. He can be contacted at email: raviraj@gsss.edu.in.