Hierarchical routing technique for traffic control in future internet architecture

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Abstract: The conventional TCP-based communication techniques are no longer effective in controlling dynamic situation of traffic congestion especially for future internet architecture. We reviewed the existing techniques and found that the problem of traffic congestion pertaining to heterogeneous wireless network is still not resolved. The design principle adopted in our research discusses the network architecture that is suitable for node deployment, mobility, routing, and evaluation of QoS requirement for future internet. The significance of the outcomes is being measured through QoS parameters like data transmission, channel capacity and energy dissipation. The results show that proposed routing scheme offers an efficient control over congestion in future internet.

Keywords: congestion control; future internet architecture; distributed network; routing; network traffic control; quality of service; hierarchical routing; heterogeneous network; node mobility; energy consumption.


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1 Introduction

In the present era, the internet is basically managed by various stakeholders, whose architecture is not exposed for the purpose of analysis or investigation. It just offers the execution of applications from various domains and renders services. The prime objective of future internet architecture is to come up with a virtual platform for the purpose of carrying out analysis without any significant impact on the ongoing services (Xie et al., 2011). It offers a privileged where this architecture can be investigated, validated, and enhanced on real-time dynamic applications. Although, it has a long way to go, but there is another significant issue in future internet architecture that requires the attention of the researchers (Pan et al., 2011; Natarajan and Wolf, 2012). This critical issue is related to the traffic control mechanism (Lema et al., 2014). With an increasing number of the applications there is an increasing adoption of collaborative network along with generation of massive volumes of the data over internet. Such voluminous, heterogeneous, and uncertain data give rise to traffic congestion which cannot be controlled by conventional traffic congestion control algorithms over future internet architecture.

At present, there are various schemes introduced by the researchers towards traffic management but very few of them are supported by the concept of internet architecture. Discussion of existing system towards controlling traffic congestion over future internet architecture was carried out in our prior study (Krishnareddy and Rangaswamy, 2013). After reviewing existing system, it can be inferred that majority of the techniques failed in providing the stability in network traffic. As future internet supports large channel capacity, average traffic flow will eventually be very small that leads to high instability. The future internet architecture has high-bandwidth routes, which cannot be addressed by TCP-based congestion control techniques as it is highly sensitive to the channel capacity as well as end-to-end propagation delay. An existing TCP-based congestion control mechanisms acutely suffers from instability that does not support future internet architecture (Balakrishnan et al., 2007). The performance of the control mechanism decreases with the increase of delay-bandwidth product in TCP-based solution (Balakrishnan et al., 2007). As the bandwidth delay product of a unit flow for future internet architecture scales to massive data packet size, there will be unnecessary usage of round trip time (RTT) by the TCP. Moreover, it is theoretically proven that RTT is inversely proportional to throughput for TCP, which will eventually lead to degradation in the fairness (Prakash et al., 2010). Therefore, there is a need to evolve up with an important solution for mitigating congestion in future internet architecture.

Our prior study (Krishnareddy and Rangaswamy, 2015) has introduced a rate control metric using stochastic approach to enhance the control mechanism in distributed network. The base idea of the present paper is to introduce a new topological design and routing techniques for internet architecture that is theoretically and practically different from existing solutions and is also compatible with future internet architecture. Hence,
we choose not to enhance or modify any rate control metric or any existing system, but rather come up with new idea of performing a routing mechanism to minimise the congestion and meet the QoS requirement of the future internet architecture. Existing studies towards the problem is discussed in related work in Section 2. Section 3 discusses the proposed system. Result discussion is presented in Section 4 and Section 5 finally summarises the paper contribution and applicability.

2 Related work

This section discusses about the existing studies being carried out for controlling congestion over internet. Distributed networking system is a constant topic of research from the past decade; however, there is an increasing attention towards future internet architectures in last five years. As evidence, it was found that reputed institution i.e., National Science Foundation (NSF) was the first firm to work on designing architecture for future internet in 2010 as a funded project (MobilityFirst FIA Overview, 2012).

Figure 1  Future internet architecture (see online version for colours)

The prime vision of this funded project was to evolve up with novel future internet architecture. Exclusive investigation on the topic was initiated in 2013 under the supervision of Dipankar Ray Chaudhuri (GENI, 2016) who was working as director at Rutgers University in USA. The project was coined a name as MobilityFirst project. The discussion of this project can be found in the work of Seskar et al. (2011) in 2011. Figure 1 shows the original architecture of MobilityFirst project that highlights the presence of multiple domains as core network in future internet architecture. The project mainly considers designing wireless network where the access points are also connected with computing as well as storage components. The system shows a combination of various types of wireless terminals right from WLAN to WiMax and gives a true picture
of future internet architecture. The architecture also uses global name resolution service to associate the name of the network object to its present address. The security and reliability of the network is ensured by incorporating self-certified public key-based identifiers for the network objects. Therefore, inter-domain routing is present in the heterogeneous domains and terminals in a distributive manner. However, when the global network is removed, the MobilityFirst architecture can be seen as wireless ad hoc network too. Practically speaking MobilityFirst is the first prototype for future internet architecture and provides guidelines to formulate the design of distributed architecture. After studying the MobilityFirst project, following conclusions are derived:

1 The present academic research papers focuses on the hypothetical modelling of distributed network, which does not actually consider the presence of heterogeneity of the devices. There is a need to consider heterogeneity aspects where heterogeneous device will mean multiple communication devices working on different network protocols with different operating environment.

2 The present architectures discussed by prior researchers are quite stereotyped and impractical with less extent of novelty to be compatible with the future internet architecture.

3 Congestion issues were more hypothetically analysed but never analysed from the aspects of future internet. There is a need to evolve up with a new congestion control technique applicable for future internet considering the QoS requirements of the network and the system.

4 Majority of the studies does not consider mobility factor while designing distributed architecture. Presence of mobility gives rise to various channel related problems like scattering, fading, interference, delay, energy, which is found missing even in MobilityFirst project architecture.

Apart from this some relevant research work carried out in this area are as follows: Adhari et al. (2015) have presented a technique for investigating the congestion over internet using delay factor on background traffic. The complete study is about detection of congestion point in very simple manner. Bruschi et al. (2013) have correlated energy efficiency with the traffic congestion in TCP-based network. Lam and Chen (2013) have presented a congestion reduction technique that performs assignment of the rate of transmission in order to cater up the dynamic demands of the machine. Liu and Yang (2013) have presented a fuzzy-based controller design in order to control the congestion. The study focuses on distributed traffic management and attempts to enhance the service quality. Most recently, Ndikumana et al. (2015) have presented a strategy to control congestion for information centric network. The presented scheme is more predictive in nature in detecting the point of congestion and the same information is than passed on to the descendent nodes. Sharma et al. (2013) have used forward error correction method to enhance the rate control mechanism in heterogeneous network like internet-of-things. Shi et al. (2013) have presented a congestion control technique for peer-to-peer applications over internet. Talaat et al. (2013) and Yang et al. (2011) have introduced a congestion control for TCP-based traffic exclusively for real-time file transfer. Discussion of adaptive algorithms was carried out by Misra and Oommen (2004) and Misra (2004). The same authors have carried out significant works using learning automata (Misra et al., 2012), swarm intelligence (Misra and Rajesh, 2011; Misra et al., 2010c, 2010a),
security (Misra et al., 2010b), and towards routing techniques (Dhurandher et al., 2010)
mainly in ad hoc network that plays an essential role in future internet architecture. Konorski et al. (2013) have presented a
discussion toward virtualisation for secure future internet architecture. Nearly, similar kind of discussion was also presented with added
emphasis on trends on future internet architecture by Pereira and Pereira (2015). Jara et al. (2013) have presented a technique to support security over mobility management in
internet-of-things that will be integrated in future internet architecture. Hence, our
proposed study will present a novel design of network topology and routing mechanism for future internet that aims discretely to minimise the congestion and address the QoS
requirements of the future internet architecture.

3 Proposed system

The prime aim of the proposed system is to introduce a novel architecture called as
hierarchial network routing architecture (HNRA) for leveraging the performance of
distributed network. The architecture basically targets to solve the traffic congestion
problem in distributed network that is designed based on future internet architecture. In
addition to that this architecture enables for developing simple and novel routing
principle that can understand the underlying network and mobility aspects in distributed
network for better modelling of congestion.

Figure 2  Schematic diagram of proposed system of HNRA

The proposed HNRA design is highlighted in Figure 2. The first component of
architecture is deployment of nodes. The proposed system consists of different types of
nodes (heterogeneous) randomly deployed over the novel topology. The new elements of
proposed topology design are backbone node (BN), routing region (RR), and super
backbone node (SBN). This will mean that any forms of routing requirements will be
processed considering these three elements of novel topology of HNRA. The next core
component of this is the routing mechanism. Basically, the routing mechanism takes
place in two phase:
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1. first-order routing technique (FORT)
2. second-order routing technique (SORT).

Any initial query broadcasted by a sender node is processed by FORT using the mechanism of bi-directional routing vectors (BDRV). The probability of finding the destination node and delivering the packet by FORT is high. However, in case of failure, it uses SORT which works using multicasting features. Hence, there is a maximum probability of finding the destination node in SORT. Therefore, the proposed system essentially targets to implement a novel routing scheme that can cater up the dynamic demands of communication in the distributed networking system e.g., future internet architecture. It also ensures to control the traffic congestion problem in the heterogeneous network to a significant extent.

The discussion of the proposed HNRA is as follows.

3.1 Network deployment

The HNRA system considers the existence of heterogeneous nodes in the form of cluster where the mobile nodes are deployed in random as shown in Figure 3.

Figure 3 Network deployment of HNRA (see online version for colours)

The cluster formation is quite different in this scheme as compared to conventional clustering mechanism. The cluster structure differs according to the type of networks involved in communication (e.g., wireless sensor, wireless mesh and mobile ad hoc network). In conventional system a cluster is a group of nodes which operates on similar protocols or similar applications. In HNRA system, we define clusters as a defined set of locations called as RRs where any cluster can contain heterogeneous mobile nodes. The request of the node lying under one RR is initially processed by its local BN, but in case the local BN is not able to do so, the request is then forwarded to SBN. It is assumed that SBN possesses the synchronous communication with all the BNs and hence any request (for destination node) by a node from a particular BN forwarded to SBN can be processed positively. It is totally event-based request and hence does not necessarily create overhead. Although, there can be any number of RRs, but proposed system
considers RR in the order of $4^n$ ($n = 1, 2, 3$). It is observed that there are challenges in clustering heterogeneous nodes for establishing communication among them. This scenario is addressed by providing a BNs that retains the authenticated information of the mobile nodes present in RR. In RR, the BNs are placed in such a way so as to offer better coverage and connectivity among the clusters to render enhanced mobility to the pervasive users. There are two types of BNs:

1. normal BN that assists in communication in local RR
2. super BN that assist in communication of global RR.

The proposed system assumes that SBN will have protocol processing capabilities to bridge communication between two heterogeneous BNs. This formulates the new topology (HRNA) for supporting inter-domain routing in future internet architecture. The future internet architecture is a complex structure in order to handle massive dynamic traffic. This system is motivated from MobilityFirst prototype which is operated on open flow networking principle. The open flow networking principle permits the switches to decide upon the routes for the data packets. This technique supports for designing the mobility model and it is functional at the network layer of the TCP architecture. This open flow switches supports communication among heterogeneous nodes and there by the mobility in the future Internet architecture is managed. The important notation used in discussion of implementation of techniques and algorithm is tabulated in Table 1.

**Table 1** Notations used in implementation of HNRA

<table>
<thead>
<tr>
<th>Notation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a$</td>
<td>Nodes</td>
</tr>
<tr>
<td>$n$</td>
<td>degree of RR</td>
</tr>
<tr>
<td>$R_{s,d}$</td>
<td>Route between source and destination</td>
</tr>
<tr>
<td>$r$</td>
<td>Bi-directional routing vector</td>
</tr>
<tr>
<td>$M_{l,t}$</td>
<td>Matrix storing FORT routing data</td>
</tr>
<tr>
<td>$\Omega_{RR}$</td>
<td>Size of RRs</td>
</tr>
<tr>
<td>$P_{zone}$</td>
<td>Primary routing zone</td>
</tr>
<tr>
<td>$\Phi$</td>
<td>Orientation angle for directing search</td>
</tr>
</tbody>
</table>

### 3.2 Routing mechanisms

The HNRA system adopts a unique routing mechanism called FORT and second order routing technique (SORT) to overcome the congestion issues owing to higher traffic request and challenging mobility scenario. An elaborated discussion of FORT and SORT are as follows.

#### 3.2.1 First-order routing technique

FORT is basically the routing mechanism initiated by a source node by forwarding it query to the nearest BN. Generally routing mechanisms uses control messages like route request (RREQ), route reply (RREP), route error (RERR), and route acknowledgement (RACK). Here, HNRA mechanism will also be functioning on the same principle of the existing control messages but it differs in its architecture. The sender node transmits a query message to one of the nearest local BN which possess the positional information of
the nodes in the same cluster. After the query message is received by the BN, then it is forwarded to other BN in some other clusters. In case the BN finds the destination node in the same cluster it will be routed back. However, if it does not find the destination node in the process of querying, it contacts the super BN, which possess the information of the RR from other clusters. This process of the search is terminated in case the destination node is identified. FORT principle has a unique pattern of performing routing as shown in Figure 4. The discussion of FORT is carried out using the pictorial representation shown in Figure 3. The following are the sequence of operations that will happen once the query reaches the local BN in FORT:

- If the local BN has found the destination node, it routes the path information back to the sender through the established path in the same RR.
- If the local BN has not found the destination node in the same RR, it then sends query beacons in two opposite direction at same time to nearest local BN nodes positioned in different RR. The advantage of this process is less delay and higher probability of finding the destination node. We call this as BDRV in first-order routing.
- It is quite evident that the meeting point of BDRV will eventually find the destination node. In that case, the specific BN will establish a path from the sender to the destination node and perform transmission of data packet. The search mechanism is mainly designed keeping linear topology in mind. A closer look into the HNRA scheme will show that it initiates bidirectional search in two opposite direction and simultaneous peripheral search from centre (where node is located in a RR) to periphery (to other RRs and BNs). Hence, search time is highly predictive and offers reliable packet delivery in the future internet architecture.

- If the BDRV did not come across the destination node owing to dynamic mobility of destination node, then the search is continued in the next RR level.

The algorithm of FORT has two stages of routing:

1. At first the route establishes between the sender nodes and the first group of RR (RR₁) and then from RR₁ route is established among the entire BN located in RR₁.
2. In case of absence of destination node, the routing is switched from RR₁ to its second group of RR, i.e., RR₂. The search for the destination node is done in similar fashion as RR₁ in RR₂ using BDRV. The process of search for the destination node continues to the upper limit of RRs.

The algorithm initially assigns RRs in the order to 4ⁿ where a will represent number of nodes (line-2) and n will represent degree of RR. The presented assessment was carried out considering n = 3, however, it can be maximised based on the larger scale of deployment. A node from any RR will forward RREQ beacon to a particular nodes (line-3), which further formulates route from source to destination (Rₛₐ). Considering bidirectional routing vector (r) equivalent to 1 (in line-5) will mean that search will be limited to first degree of RR (that means within 4ⁿ (where n = 1) nodes only). If the node find its destination node than it receives a response or else it increases its counter (line-7–8) to further increase its degree as 2 (line-9). When r = 2, it will only mean the absence of destination node in first RR and now it has to proceed its search in the next RR [i.e., 4ⁿ (where n = 2)]. It was already discussed in the beginning that SBN assist in
protocol translation in order to reduce complexities associated with it from one RR to another RR. The steps are iterated till it finds the destination node (Line-12). With each progress of routing, essential routing information is stored in matrix of RR. Upon positive localising and establishing data transmission with destination node, the matrix is updated with respect to its size as $\Omega_{RR}$ and final values are stored in matrix $M_{AX}$.

**Figure 4** First-order routing technique (see online version for colours)

The implemented algorithm for FORT is as described below.

**Algorithm**: first order routing in HNRA

**Input**: $RR_1(4^1), RR_2(4^2), RR_3(4^3)$

**Output**: generation of first route $\Omega_{AX}$

**START**

1. Assign $RR_1, RR_2, RR_3$ in order to $4^n$ [$n = 1, 2, 3, \ldots$]
2. Create $a = \{a_1, a_2, a_3, \ldots, a_m\}$, where $m = 4^n$ (RRs).
3. Initiate query process (search in $RR_1$)
4. Assign $R_{x,y} = r_i, R_{x,x} = r_j$
5. $r_i = 1$
6. If ($j = 0, j++$, $j \leq 4$) [here 4 represents $4^n$ ($n = 1$)]
7. Increment count for $r_y$
8. Continue query process (search in $RR_2$)
9. $r_k = 2$
10. If ($j = 0, j++$, $j \leq 16$) [here 16 represents $4^n$ ($n = 2$)]
11. Increment count for $r_y$
12. Repeat step-10 till $a_m$
13. Create a matrix of RR
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\[ \Omega_{\text{rx}} = \text{update} \left( \sum_{n=1}^{m} a_n \right), \ m \text{ is natural numbers} \]

Store \( M_{\text{rx}} \)

3.2.2 Second-order routing technique

SORT is meant to provide an additional support of routing in case if FORT fails to explore the destination node owing to dynamic topology. It works on the principle of multicasting the routing message in order to minimise the time require for searching the destination node for data packet delivery. The first-order routing ensures the search for the destination node and also finds stable routes between the queried node (sender) and destination nodes. There can be possibilities like:

1. destination nodes has moved to different RR or it is missed by searching procedure of BDRV
2. due to the presence of non-functional BN.

**Figure 5**  Second-order routing technique (see online version for colours)

In such cases FORT may fail to detect the destination. Although, there is less probability for a BN to be non-functional, but HNRA system considers this for worst scenario of device failures. In order to enhance the search procedure discussed in FORT, a recursive search process is added termed as SORT and is schematically shown in Figure 5.

The SORT will be initiated only if the BN fails to find the destination node using FORT. In this case the last BN will transmit an RERR message to the sender node after it converges at higher group of RR. The sender node on receiving the RERR message it will start adopting the routing policy specific to second-order routing. In this case, the BDRV will be non-functional. The generated request from the source node is forwarded to the local BN, which will be communicated directly to the nearest global backbone. This
process is faster than the FORT. In FORT, one BN send the request message to only two local BN at a same time, but in second-order technique, one BN performs multicasting to three global beacons at a same time. In case of positive search, the RREP message is transmitted back to sender node or else the similar search continued with other local BN. The SORT is a general function for energy-constraint resources in future internet architecture. Owing to adoption of Open Flow technology, there is no additional load of data processing when performing communication among the heterogeneous network devices. The route request message is represented as \( r_i \) and reply message is represented as \( r_j \). The connection is basically from \( RR_1 \) to \( RR_2 \) and then if required to \( RR_3 \). In the Figure 5, there is a possibility of one BN in \( RR_1 \) getting connected with 3 BN residing in \( RR_2 \). The \( R_{s,d} \) represents the established route between sender \( s \) and destination \( d \). The SORT ensures connectivity to the destination node provided destination has not moved out of transmission zone or it is depleted of battery power.

**Algorithm:** second-order routing in HNRA.

**Input:** \( \Omega_{RR}, \Phi \)

**Output:** \( R_{s,d} \)

**START:**

1. Find size of \( \Omega_{RR} \).
2. Evaluate orientation phase for initiating search \( \phi = \frac{360 \times \text{vector}(j)}{360} \)
3. Update query process
4. Assign \( R_{s,d} = r_i \)
5. For \( P_{zone} \)
6. Estimate \( R_{s,d} + r_j A \sum_{n=1}^{3} RR_2 \)
7. Return value \( R_{s,d} \)

**END**

One important aspect of FORT and SORT algorithms is its success or failure rate. Following are some of the essential points to validate it:

- The matrix \( M_{xz} \) is regularly updated upon completing the search (whether it is positive or negative in finding the destination node). Hence, updates travel to all the BN via SBN informing about the routing status. This further result in narrowing the search result that brings the communication vector more closely to destination node.

- The speed of search and request processing of SORT is faster than FORT. It is because FORT performs the check in only one direction but SORT performs parallel checks in all the direction using bidirectional beacons. Hence, HNRA can cater up the coverage and connectivity requirement of the dynamic networks.

The proposed routing technique is quite different from existing routing technique over wireless network in context of:

1. novel topology construction
2. novel steps of routing (FORT, SORT) to ensure data delivery
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3 hierarchical nature of routing that provides energy efficiency.

The next section discusses about result accomplished from the proposed work.

4 Result discussion

The HNRA system is implemented through Matlab. The outcomes are analysed with respect to parameters like data transmission, channel capacity, and energy consumption. An effective routing scheme is anticipated to offer seamless communication performance which can be checked through data transmission parameter. Owing to uncertain and unpredictable traffic condition, there is a possibility of over utilisation or underutilisation of bandwidth. A robust routing principle should offer an effective service delivery on time which can be only validated by its effect on channel capacity parameter. It has to ensure a optimal usage of channel capacity in order to prove its cost effectiveness. Finally, as the routing protocols follows hierarchical scheme, it is essential to maintain higher network lifetime. This fact can be testified using energy. An energy efficient routing scheme is anticipated to conserve more energy of the low-powered communicating nodes. The simulation parameters considered for performing result analysis are highlighted in Table 2.

Table 2 Simulation parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation area</td>
<td>1,000 × 1,000 m²</td>
</tr>
<tr>
<td>Node speed</td>
<td>10–50 m/s</td>
</tr>
<tr>
<td>Mobile nodes</td>
<td>100</td>
</tr>
<tr>
<td>BNs</td>
<td>Tested with 12 BN, 18 BN, 24 BN</td>
</tr>
<tr>
<td>Energy</td>
<td>Initial energy: 0.5 J</td>
</tr>
<tr>
<td></td>
<td>$E_{TX}$: 0.005 J</td>
</tr>
<tr>
<td></td>
<td>$E_{RX}$: 0.003 J</td>
</tr>
<tr>
<td>Data packet length</td>
<td>6,400 bytes</td>
</tr>
<tr>
<td>Control packet length</td>
<td>200 bytes</td>
</tr>
</tbody>
</table>

The HNRA scheme is implemented and the observation is recorded for both FORT and SORT algorithm. This scheme offers a novel topology over which FORT and SORT algorithms are implemented with random mobility patterns for the nodes. The evaluation of the proposed system is also compared with an existing system to measure its effectiveness.

4.1 Impact of energy on routing packets

The prime purpose of this evaluation is to evaluate an impact of different variants of residual energy of mobile nodes on routing packets generated. The rationale behind this evaluation is that if the number of mobile nodes increases, the traffic request will exponentially increase. It is also considered to understand the dependency of energy towards generating more routing data for supporting heavy traffic condition in distributed network architecture.
Figure 6 highlights the simulated outcome of the proposed system for analysing number of routing packets delivered per request with increasing number of nodes. The simulation has been carried out by three different types of observation with respect to initialised energy of 0.75 J, 0.50 J, and 0.25 J. The curve shows that when the initialised energy is 0.25 J, the data transmission rate has slow increment. The rate of data transmission was found increasing when the energy of the node increases to 0.5J. Further with increase in the energy to 0.75 J, the routing system exhibited better performance in data delivery. However, with an existence of next generation wireless routers with enhanced amplification capabilities, energy will not be an impending factor towards data delivery.

4.2 Impact of packet size on channel capacity

The prime purpose of this evaluation is to check the impact of different packet size on channel capacity in distributed networking system. As channel capacity is one of the scarce resources, the analysis will test whether the increasing traffic (with bigger packet size) can be processed with lowered channel capacity. Figure 7 exhibits the performance of average channel capacity. The future internet architecture supports high data rate (bandwidth), but still user behaviour remains a challenge. To understand the impact of increasing date rate on channel capacity with increasing node count the simulation was carried out with different size (experimental) of data packets. It is found that with the increase in packet size, the required channel capacity is decreasing. The reason for this scenario is that it is not using conventional shortest path technique to perform routing but it uses the principle of first-order and second-order routing to perform communication. The first-order routing has bi-directional pattern of forwarding the data packet, where the search for the destination node is accelerated twice in comparison to shortest path routing mechanism. In case of node failure or congestion, the first-order routing detects the region of congestion and finds an alternative path to route the data packet. Moreover, the second-order routing increases the reliability of forwarding the data. With the availability of the super-BN the connectivity among heterogeneous nodes also improves. The
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availability of the routes improves the communication and optimises the QoS requirements of the network.

Figure 7  Average channel capacity performances (see online version for colours)

Increase in number of node will mean increasing request packets originating in the wireless media which needs to be processed. As majority of the nodes are assumed to follow IEEE wireless standards and it is expected to have retransmission effect that results in greater number of packets with the increase in number of nodes. This will definitely utilise more channel capacity for the initial test packet size of 100 bytes. However, it should not increase very instantly, hence, it can be seen that the curve increase quite slowly. But with the presence of proposed routing scheme, it is observed that increase of nodes (n = 200) have no significant impact on channel capacity in longer run. The next parameter under evaluation is the energy metric for the nodes with respect to mobility. Especially in case of mobile networks (MANET/VANET), where the nodes are in constant move, there is a spontaneous dissipation of energy leading to reduction in the lifetime of the network. This system offers following advantages:

1  it incorporates BN and Super BN, which reduces the data processing operation as well as route discovery operation thereby saving a fair amount of energy of the mobile nodes

2  it also offers a super BN, which is assumed to adopt open flow technology that can significantly reduce the data discovery time as well as perform validation of the control messages.

In this system, significant amount of energy is conserved and the routing capability of the nodes is improved. Usually, the nodes are power constraint, but they are backed up by external battery to perform their operation. Therefore, with increased mobility, depletion of external battery is quite evident.

The nodes present in our network are of heterogeneous types and has different physical properties. The two different nodes processing same data will consume different
amount of energy. According to the theory of energy management in wireless networking system the power dissipation can be controlled if the rate of power dissipation of nodes is uniform. In our proposed system first-order radio-energy model is used to ensure that optimal energy is utilised for transmitting data packets.

4.3 Impact of packet size on energy consumption

This part of the evaluation essential checks for the impact of increasing traffic (represented by different packet size) over the energy consumption of the mobile nodes in distributed networking system.

Figure 8 Energy consumption per packet (see online version for colours)

Figure 8 highlights the energy consumption per packet owing to mobility. From the above graph it is evident that even if there is an increase in the speed of nodes there will not be much change in the quality factor of the communication including energy consumption. Hence, in our system the architecture supports for the mobility by collecting significant information of the nodes from local and global BNs in RRs. The BN is loaded with relevant information of the nodes and also the local BNs when the rounds of simulation are increased which help in search of destination node and so a fair amount of energy can be conserved.

4.4 Comparative analysis

The outcome of the proposed study was also compared with the recent work being carried out Liu and Yang (2013) who have used fuzzy logic to perform congestion control. We carry out the investigation of the proposed system with Liu and Yang (2013) with respect to energy efficiency on similar test-bed of HNRA. A closer look into the previous works will infer that conventional TCP-based scheme has issues with respect to congestion and traffic management. Moreover the existing algorithms will no longer use TCP-based
approaches in future internet architecture for congestion control. Hence, for this purpose, we compare our work with Liu and Yang (2013) which implements concepts very similar to us and hence best suited for comparative analysis. Similar membership functions were developed in Matlab using fuzzy toolbox. We initiated the simulation by incrementing the request of traffic by 1,000 bytes in proposed distributed architecture.

Figure 9 Comparative analysis of energy consumption (see online version for colours)

Figure 9 shows the comparative analysis of proposed system with Liu and Yang (2013). We choose to consider energy consumption as prime performance parameter in this comparative analysis because future internet architecture is going to open the door for many applications that can be directly accessible from user’s terminal which will be usually battery operated. Hence, resisting the battery drainage for prolonged time will mean always the cost-efficient traffic control protocol from user experience viewpoint. The outcome directly shows that our work excels better in comparison to existing system with respect to energy conservation.

5 Conclusions

The existing routing mechanism and the underlying network topology fail to support congestion free traffic in the distributed network system as they do not consider the heterogeneity of the nodes. The first contribution of proposed HNRA system is to address the above problem by proposing the novel routing mechanisms namely FORT and SORT. This routing mechanism with the help of bidirectional pattern of query forwarding technique enhances the availability of routes to the destination thereby improving the communication and optimises the QoS requirements of the network. The second contribution is its presented topology which is quite different from existing internet
architecture that commonly supports cellular networks. The presented approach can be directly mapped with inter-of-things or any forms of heterogeneous network, which are some of the essential characteristics of future internet architecture. The third contribution is that its concept is simple and yet robust which reduces the congestion and enhanced the QoS of communication. The fourth contribution is that it offers better control over the dynamic congestion even though this system is not adopting the concept of load balancing or queuing mechanism. Our future work will focus on investigating the feasibility of implementing cross-layer approach to control congestion in the future internet architecture.

References


Hierarchical routing technique for traffic control


