Hybrid Wireless Network Based on DTR [Distributed Three Hop Routing Protocol]

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***Abstract*: Wireless networks using Hybrid technology combining the advantages of both infrastructure wireless networks and mobile ad-hoc networks and have been receiving increased attention due to their ultra-high performance. For high network capacity and scalability, an efficient data routing protocol is important, However, most protocols standard for these networks simply combine the routing principles namely ad-hoc Transmission mode with the advance technique included as cellular transmission mode, which in return inherits the drawbacks of ad-hoc transmission. This paper presents a Distributed Three-hop Routing protocol (DTR) for wireless networks using hybrid technology. Achieving full advantage of the widespread of base stations, a message data stream can be divided into segments and transmits the segments in a distributed approach. It makes full orbital (spatial) reuse of a system via its ad-hoc interface and alleviates mobile gateway congestion via its cellular interface with faster speed or high speed. Furthermore, passing segments to a number of base stations simultaneously, it increases throughput and makes complete use of base stations which are widespread. In addition to this, DTR relatively lowers overhead due to short path lengths and it terminates of route discovery and maintenance. DTR is also having congestion control algorithm to disapprove overloading of base stations. Theoretical simulation analysis and results show the dominance of DTR in evaluation with other routing protocols in terms of throughput capacity, scalability and mobility pliability. The Results also show the helpfulness of the congestion control algorithm in balancing the load between base stations.**

Keywords— Hybrid wireless networks, Routing algorithm, Load balancing, Congestion control Introduction.

I. INTRODUCTION

In past few years, wireless networks including Transportation wireless networks and mobile ad-hoc networks (MANETs) have paying attention significantly to explore interest. The mounting yearning to increase wireless network Capacity for high performance applications has encouraged the development of hybrid wireless networks [1]. A hybrid wireless network consists of both a transportation Wireless network and a mobile adhoc network. Wireless devices such as smart-phones, tablets and laptops, Have both an infrastructure interface and an adhoc Interface. As the number of such devices has been escalating sharply in recent years, hybrid communication Structure will be broadly used in the near outlook. Such a Structure specially combines the Inherent advantages and overcome the disadvantages of the infrastructure wireless networks and mobile ad-hoc networks

In a mobile ad-hoc network, with the absence of central control transportation, data is routed to its target through the intermediate nodes in a multi-hop manner. The multi-hop routing needs on-demand route discovery or route maintenance. Since the messages are transmitted in wireless channels and through dynamic routing paths, mobile ad-hoc networks are not as reliable as infrastructure wireless networks. Furthermore, because of the multi-hop transmission feature, mobile ad-hoc networks are only suitable for local area data transmission. The infrastructure wireless network (e.g. cellular network) is the major means of wireless communication in our daily lives. It excels at inter-cell communication (i.e., communication between nodes in different cells) and Internet access. It makes possible the support of universal network connectivity and ubiquitous computing A hybrid wireless network synergistically combines an infrastructure wireless network and a mobile adhoc Network to leverage their advantages and overcome Their shortcomings, and finally increases the throughput capacity of a wide-area wireless network. A routing protocol is a critical component that affects the throughput capacity of a wireless network in data transmission. Most current routing protocols in hybrid wireless networks simply combine the cellular transmission mode (i.e. BS transmission mode) in infrastructure wireless networks and the ad-hoc transmission mode in mobile ad-hoc networks .That is, as shown in Figure 1 (a), the protocols use the multi-hop Routing to forward a message to the mobile gateway nodes that are closest to the BSes or have the highest bandwidth to the BSes. The bandwidth of a channel is the maximum throughput (i.e., transmission rate in bits/s) that can be achieved. The mobile gateway nodes then forward the messages to the BSes, functioning as bridges to connect the ad-hoc network and the infrastructure network. However, direct combination of the two transmission modes inherits the following problems that are rooted in the ad-hoc transmission mode. High overhead. Route discovery and maintenance incur high overhead. The wireless random access medium access control (MAC) required in mobile ad-hoc networks, which utilizes control handshaking and a back off mechanism, further increases overhead.

Hotspots. The mobile gateway nodes can easily become hot spots. The RTS-CTS random access, in which most traffic goes through the same gateway and the flooding, employed in mobile ad-hoc routing to discover routes.

II. RELATED WORKS

In order to increase the capacity of hybrid wireless networks, various routing methods with different features Have been proposed. One group of routing methods integrate the ad-hoc

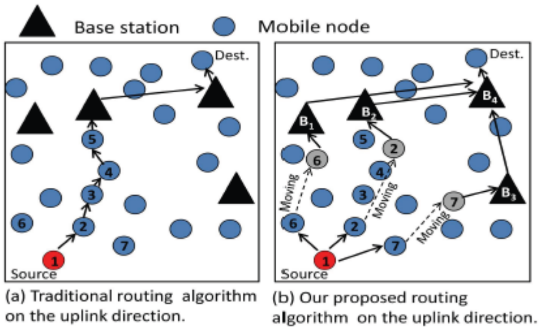


Fig. 1: Traditional and proposed routing algorithms on the uplink direction.

Transmission mode and the cellular transmission mode [1, 5, 6, 14, 16–18]. Dousse et al. [6] built a Poisson Boolean model to study how a BS increases the capacity of a MANET. Lin et al. [5] proposed a Multihop Cellular Network and derived its throughput. Hsieh et al. [14] investigated a hybrid IEEE 802.11 network architecture with both a distributed Coordination function and a point coordination function.

Luo et al. [1] proposed a unified cellular and ad-hoc network architecture for wireless communication. Cho et al. [16] studied the impact of concurrent transmission in a downlink direction (i.e. from BSes to mobile nodes) on the system capacity of a hybrid wireless network. In inter-cell transmission [1, 5, 6], a message is forwarded via the ad-hoc interface to the gateway mobile node that is closest to or has the highest uplink transmission bandwidth to a BS. DTR is similar to the Two-hop transmission protocol [19] in terms of the elimination of route maintenance and the limited number of hops in routing. In two-hop, when a node's bandwidth to a BS is larger than that of each neighbor, it directly sends a message to the BS. Otherwise, it chooses a neighbor with a higher channel and sends a message to it, which further forwards the message to the BS. DTR is different from two-hop in three aspects. First, Two-hop only considers the node transmission within a single cell, while DTR can also deal with inter-cell transmission, which is more challenging and more common than intra-cell communication in the real world. Second, DTR uses distributed transmission involving multiple cells, which makes full use of system resources and dynamically balances the traffic load between neighboring cells. In contrast, Two-hop employs single-path transmission.

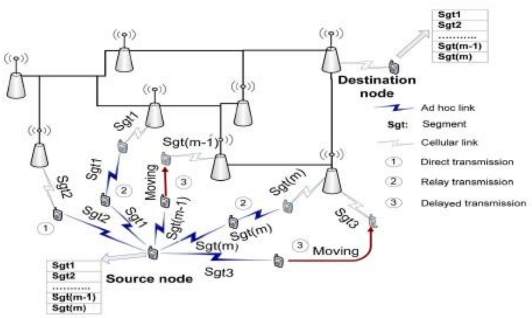


Fig. 2: Data transmission in the DTR protocol.

There are other methods proposed to improve routing performance in hybrid wireless networks. Wu et al. [3] proposed using ad-hoc relay stations to dynamically relay traffic from one cell to another in order to avoid traffic congestion in BSes. Li et al. [20] surveyed a number of multi-hop cellular network (MCN) architectures in literature, and compared and discussed methods to reduce the cost of deployment for MCNs and an optimal multicast strategy based on deduced throughput

III. DISTRIBUTED THREE-HOP ROUTING PROTOCOL

A. Assumption and Overview

Since BSes are connected with a wired backbone, we assume that there are no bandwidth and power constraints on transmissions between BSes. We use intermediate nodes to denote relay nodes that function as gateways connecting an infrastructure wireless network and a mobile ad-hoc network.We assume every mobile node is dual-mode; that is, it has ad-hoc network interface such as a WLAN radio interface and infrastructure network interface such as a 3G cellular interface Our DTR algorithm avoids the shortcomings of adhoc transmission in the previous routing algorithms that directly combine an ad-hoc transmission mode and a cellular transmission mode. Rather than using the multihop ad-hoc transmission, DTR uses two hop forwarding by relying on node movement and widespread base stations. All other aspects remain the same as those in the previous routing algorithms (including the interaction with the TCP layer).

B. Uplink Data Routing

Specifically, in the uplink routing, a source node initially divides its message stream into a number of segments, then transmits the segments to its neighbor nodes. The neighbor nodes forward segments to BSes, which will forward the segments to the BS where the destination resides. Below, we first explain how to define capacity, then introduce the way for a node to collect the capacity information from its neighbors, and finally present the details of the DTR routing algorithm.

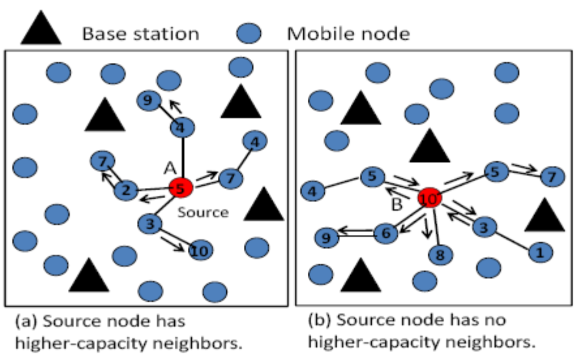


Fig. 3: Neighbor selection in DTR.

C. Downlink Data Routing and Data Reconstruction

In this protocol, each mobile node is The home network of a node contains its registration information identified by its home address, which is a static IP address assigned by an

ISP. In a hybrid wireless network, each BS periodically emits beacon signals to locate the mobile nodes in its range.

D.Congestion Control in Base Stations

In the hybrid wireless network, BSes send beacon messages to identify nearby mobile nodes. Taking advantage of this beacon strategy, once the workload of a BS, say Bi, transmission range. Then, nodes near Bi know that Bi is overloaded and will not forward segments to Bi. When a node near Bi, say mi, needs to forward a segment to a BS, it will send the segment to Bi based on the DTR algorithm.

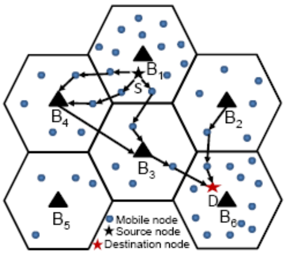


Fig. 4: Congestion control on BSes.

IV. EXISTING SYSTEM

In existing system, they follow the basics concepts of Routing algorithm, and they can be explains through the following algorithms.

Algorithm 1 Node A finds the next hop routing grid based on the EBC $\alpha \in [0,1]$

1: Compute the average remaining energy of the adjacent neighboring grids: $\mathcal{E}_a(A) = \frac{1}{|\mathcal{N}_A|}\sum_{i\in\mathcal{N}_A}\mathcal{E}r_i$.
2: Determine the candidate grids for the next routing hop: $\mathcal{N}_A^\alpha = \{i \in \mathcal{N}_A \,|\, \mathcal{E}r_i \geq \alpha\mathcal{E}_a(A)\}$.
3: Send the message to the grid in the $\mathcal{N}_A^\alpha$ that is closest to the sink node based on its relative location.

Algorithm 2 Node A finds the next hop routing grid based on the given parameters $\alpha, \beta \in [0,1]$

1: Compute the average remaining energy of the adjacent neighboring grids: $\mathcal{E}_a(A) = \frac{1}{|\mathcal{N}_A|}\sum_{i\in\mathcal{N}_A}\mathcal{E}r_i$.
2: Determine the candidate grids for the next routing hop: $\mathcal{N}_A^\alpha = \{i \in \mathcal{N}_A \,|\, \mathcal{E}r_i \geq \alpha\mathcal{E}_a(A)\}$.
3: Select a random number $\gamma \in [0,1]$.
4: **if** $\gamma > \beta$ **then**
5: Send the message to the grid in the $\mathcal{N}_A^\alpha$ that is closest to the sink node based on its relative location.
6: **else**
7: Route the message to a randomly selected grid in the set $\mathcal{N}_A^\alpha$.
8: **end if**

After computing these algorithms their output is as shown

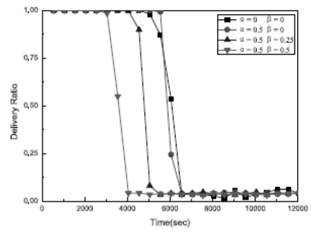


Fig. 7. Delivery ratio under different EBC α and security level β.

TABLE 1
Routing Hops for Different EBC Parameters
$(\mu' = 200, \sigma' = 50\sqrt{2})$

EBC parameter	Average hops in simulations	Estimated CASER hops
0	10	10
0.1	10.26	10.05
0.2	10.38	10.09
0.3	10.63	10.18
0.4	11.02	10.34
0.5	11.15	10.64

TABLE 2
Routing Hops for Various Security Parameters (The Simulation Was Performed Using OPNET)

Security parameter β	Average hops in simulations	Estimated CASER hops
0	10.00	10.00
0.125	11.97	11.46
0.25	14.51	13.52
0.375	17.98	16.70
0.5	23.34	22.36

and their output sis tabulated as shown above. These Disadvantages can be overcome through DTR algorithms and protocols

V.PERFORMANCE ANALYSIS OF THE DTR PROTOCOL

DTR

Achieves higher throughput and faster data forwarding speed by taking into account node capacity in data forwarding.

Algorithm 1 Pseudo-code for neighbor node selection and message forwarding.

ChooseRelay( ) {
//choose neighbors with sufficient caches and bandwidth/queue (b/q) rates
Query storage size and QoS requirement info. from neighbors
for each neighbor n **do**
  if n.cache.size>segment.length && n.b/q>this.b/q **then**
    Add n to $\mathcal{R} = \{r_1, \ldots r_m, \ldots\}$ in a descending order of b/q
  end if
end for
Return $\mathcal{R}$
}
Transmission( ) {
if it is a source node **then**
  //routing conducted by a source node
  //choose relay nodes based on QoS requirement
  $\mathcal{R}$=ChooseRelay( );
  Send segments to $\{r_1, \ldots r_m\}$ in $\mathcal{R}$
else
  //routing conducted by a neighbor node
  if this.b/q $\leq$ b/q of all neighbors **then**
    //direct transmission
    if within the range of a BS **then**
      Transmit the segment directly to the BS
    end if
  else
    //relay transmission
    $node_i$=getHighestCapability(ChooseRelay( ))
    Send a segment to $node_i$
  end if
end if
}

Algorithm 2 Pseudo-code for a BS to reorder and forward segments to destination nodes.

//a cache pool is built for each data stream
//there are n cache pools currently
if receives a segment (S,D,m,s,q) **then**
  if there is no cache pool with msg sequence num equals m **then**
    Create a cache pool $n+1$ for the stream m
  else
    //the last delivered segment of stream m has sequence num $i-1$
    if $s == i$ **then**
      Send out segment (S,D,m,s,q) to D
      $i++$;
    else
      Add segment (S,D,m,s) into cache pool m
    end if
  end if
end if

Besides mobile nodes, there are M BSes regularly deployed in the field. The BSes divide the area into a Hexagon tessellation, in which each hexagon has side Length h. DTR and DHybrid avoid long distance transmissions, leading to a higher transmission throughput.

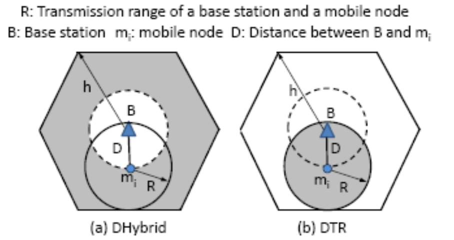


Fig. 5: The traffic load in DHybrid and DTR.

1. *PERFORMANCE EVALUATION*

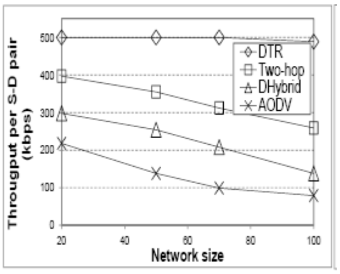


Fig. 6: Throughput vs. network size (simulation).

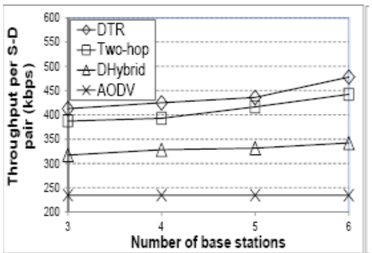


Fig. 7: Throughput vs. number of BSes.

The short routing paths in Two-hop reduce congestion and signal interference, thus enabling better spatial reuse as in DTR. As a result, gateway nodes connecting mobile nodes and BSes are not easily overloaded. Therefore, the throughput of two-hop is higher than Existing system.

2. *Scalability*

Figure 6 shows the average throughput measured in kbps per S-D pair of different routing protocols versus the number of mobile nodes in the system. The figure shows the throughput of DTR remains almost the same with different network sizes.

B. Transmission Delay

Figure 8 shows the average transmission delay of SD pairs for successfully delivered messages in different routing protocols versus network size. The network size was varied from 20 to 100 with 20 increase in each step.

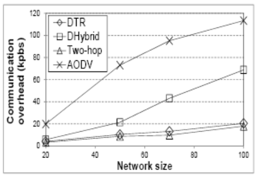


Fig. 10: Overhead vs. network size

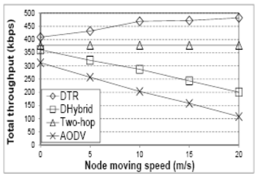


Fig. 11: Throughput vs. mobility.

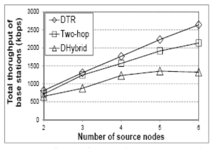
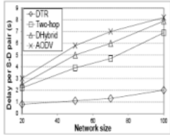


Fig. 12: Throughput of BSes vs. number of source nodes.



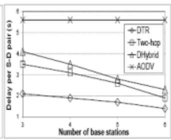


Fig. 8: Delay vs. network size. Fig. 9: Delay vs. number of B-Ses.

From the figure, we see that DTR generates the smallest delay. In DTR, each source node first divides its messages into smaller segments and then forwards them to the nearby nodes with the highest capacity, which leads to more balanced transmission load distribution among nodes than the previous methods.

C. Effect of mobility

Figure 11 plots the throughput of DTR, DHybrid, Two-hop, and AODV versus node moving speed. From the figure, we can see that the increasing mobility of the nodes does not adversely affect the performance of DTR and Two-hop. It is intriguing to find that high mobility can even help DTR to increase its throughput and that Two-hop generates constant throughput regardless of the mobility. This is because the DTR and Two-hop transmission modes do not need to query and rely on multi-hop paths; thus, they are not affected by the network partition and topology changes.

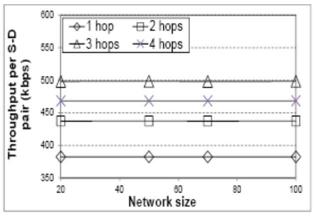


Fig. 13: Throughput vs. number of hops.

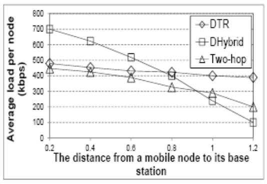


Fig. 14: Load distribution in a cell.

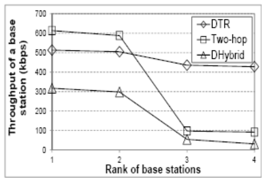


Fig. 15: Load distribution among BSes.

D. Load Distribution within a Cell

In this experiment, we tested the load distribution of mobile nodes in a randomly chosen cell in the hybrid wireless network that employs each of the DTR, DHybrid, and Two-hop protocols. We normalized the distance from a mobile node to its base station according to the function D/Rb , where D is the actual distance and Rb is the radius of its cell.

We divided the space of the cell into several concentric circles and measured the loads of the nodes on each circle to show the load distribution.

E. Effect of the Number of Routing Hops

We conducted experiments to show the optimal number of routing hops for the routing in hybrid wireless networks. We tested the throughput per S-D pair for x- hop DTR, where x was varied from 1 to 4. In the 1-hop routing, a node directly transmits a message to the BS without message division. In the other routing protocols, the (x□1) th hop chooses the best transmission mode between direct transmission and relay transmission. Also, in the 4-hop routing, the second relay node randomly the third relay node. Figure 13 shows the average throughput per S-D pair versus network size in DTR. As the figure shows, as the network size increases, the node throughput keeps constant regardless of the number of forwarding hops in a routing. The reason is the same as in Figure 6. We can also see from the figure that the throughput of the four protocols follows 3-hop>4-hop>2-hop>1-hop. In The 1-hop routing, each node only transmits segments directly to a BS regardless of its current transmission rate. In the 2-hop routing, if the transmission rate of a node's neighbor is higher than that of the node, it asks its neighbor node to forward the segment to a BS.

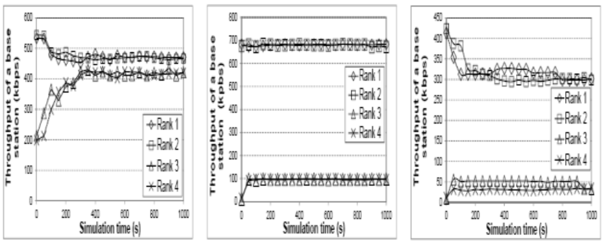
Therefore, the 2-hop routing has higher throughput than The 1-hop routing. The 3-hop routing can greatly increase the number of node options for segment routing since the number of nodes that the source node can encounter increases from d to d2, where d is the average node degree. Thus, a node with a greater transmission rate can be chosen as the forwarding node. Meanwhile, the 3-hop routing can greatly facilitate inter-cell communication because a node has a higher probability of reaching a neighboring BS within a 3-hop path length than within a 2-hop path length. Therefore, the throughput of the 3-hop routing is much higher than that of the 2-hop routing. The figure also shows that the 4-hop routing produces lower throughput than the 3-hop routing. The reason is that 3 hops are enough to find a hop with high transmission rate and achieve inter-cell communication because of widespread BSes. The 4-hop routing increases the forwarding delay due to the greater number of nodes in a route; thus, it cannot increase the uploading transmission rate of messages.

F. Load Distribution within a Cell

In this experiment, we tested the load distribution of mobile nodes in a randomly chosen cell in the hybrid wireless network that employs each of the DTR, DHybrid, and Two-hop protocols. We normalized the distance from a mobile node to its base station according to the function D/ Rb , where D is the actual distance and Rb is the radius of its cell. We divided the space of the cell into several concentric circles and measured the loads of the nodes on each circle to show the load distribution. Figure 14 shows the average load of a node corresponding to the normalized distance from itself to the BS in the chosen cell. The figure shows that most of the traffic load of DHybrid is located at nodes near the BS. The nodes far from the BS have very low load. The results conform to Proposition 4.3. In DHybrid, if a source node wants to access the Internet backbone or engage in inter-cell communication, it transmits the messages to the BSes in a multi-hop fashion. Therefore, the nodes near the BSes will have the highest load. On the other hand, since there is little traffic going through the nodes at the brim of a cell, the load of these nodes is small. As a result, some nodes can easily become hot spots while the resources of other nodes are not fully utilized. This load imbalance prevents DHybrid from fully utilizing system resources. The traffic load of DTR is almost evenly distributed in the system.

G. Load Balance between Cells

In this experiment, we tested the effectiveness of the Congestion control algorithm in DTR. We also added a Congestion control algorithm to DHybrid. In the algorithm, when a node receives beacon messages from its BS indicating that it is overloaded, the node broadcasts a query message to find a path to a nearby uncongested BS. We selected two BSes out of the total four BSes. In the range of each of the two selected BSes, we randomly selected one mobile node as the source node to send messages to a randomly selected destination node in the network. Once the source node moves out of the range of the selected BS, another mobile node in the range was selected as the source node. In order to show the load distribution of the BSes in different protocols, we ranked the BSes based on BS throughput. The BS with the highest throughput has a rank of 1.



(a) DTR (b) Two-hop (c) DHybrid

Fig. 16: Base station load vs. simulation time.

TABLE II

DEFAULT VALUES USED FOR EACH REFERENCE CURVE.

K	$r^2_{\rm rms}$	σ^2_g	σ^2_h	$\sigma^2_{\Delta g}$	$\sigma^2_{\Delta h}$	M_0	N_0	$P_{\rm max}$	$P_{\rm tot}$
20	1	2	2	0	0	2	2	2	10

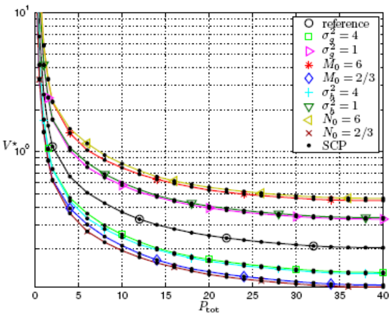


Fig. 3. The behavior of V^* from equation (76) with respect to $P_{\rm tot}$ is visualized together with the numerical results obtained by computation of the SCP (86). All curves show a decreasing property in $P_{\rm tot}$. The reference curve has the default parameters $\sigma^2_g = 2$, $\sigma^2_h = 2$, $M_0 = 2$ and $N_0 = 2$. The results of the SCP for sufficiently large number of iterations are equivalent to the closed-form solutions.

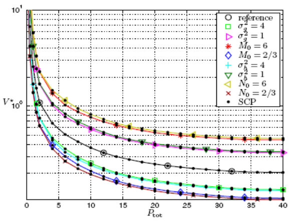


Fig. 3. The behavior of $V^\star$ from equation (76) with respect to P_{tot} is visualized together with the numerical results obtained by computation of the SCP (86). All curves show a decreasing property in P_{tot}. The reference curve has the default parameters $\sigma_g^2 = 2$, $\sigma_h^2 = 2$, $M_0 = 2$ and $N_0 = 2$. The results of the SCP for sufficiently large number of iterations are equivalent to the closed-form solutions.

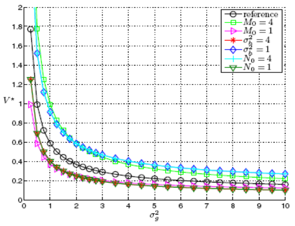


Fig. 4. Behavior of $V^\star$ with respect to σ_g^2. All curves show a decreasing property in σ_g^2. The reference curve has the default parameters $\sigma_h^2 = 2$, $M_0 = 2$ and $N_0 = 2$.

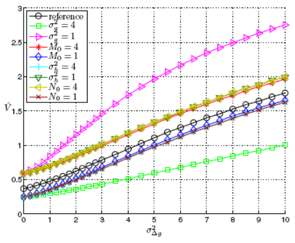


Fig. 6. Behavior of $\hat{V}$ with respect to $\sigma_{\Delta g}^2$. All curves show an increasing property in $\sigma_{\Delta g}^2$. The reference curve has the default parameters $\sigma_g^2 = 2$, $\sigma_h^2 = 2$, $M_0 = 2$ and $N_0 = 2$.

CONCLUSIONS

In this paper, we propose a Hybrid Wireless Network of Distributed Three-hop Routing (DTR) data routing protocol that integrates the duo-features of hybrid wireless networks in the data transmission process. In DTR, a source node is divided into a message stream and then into segments and further they transmits them to its itinerant neighbors, which further advance the segments to their final destination via a communications network. DTR sets the limits of the routing path length to three, and always arranges for high-capacity nodes to advance the data. Different most existing routing protocols, DTR produces considerably lowers transparency by terminating route discovery and maintenance. In accumulation, its distinguishing characteristics of short path length, short-distance transmission, and balanced load distribution provide high routing steadfastness and competence. DTR also has a congestion control algorithm to avoid load congestion in BSes in the case of unbalanced traffic distributions in networks. Notional analysis and replication results show that DTR can spectacularly improve the throughput capacity and scalability of hybrid wireless networks due to its high scalability, efficiency, and consistency and low overhead.

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