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Wireless Ad-hoc Networks Performance Evaluation Using NS-2 and NS-3 Network Simulators

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***Abstract*: An Ad-hoc network is a collection of wireless terminals that are able to dynamically form a temporary network without any aid from fixed infrastructure or centralized administration. In recent years, another class of adhoc networks are continuing to attract the attention for their potential use in several fields. Mobility and the absence of any fixed infrastructure make mobile Ad-hoc network very attractive for mobility and rescue operations and time-critical applications. In this paper, we concentrate on performance evaluation of wireless ad-hoc network using ns-2 and ns-3 network simulators. We compared the throughput simulation results of ns-2 and ns-3 with experimental results for Linear Topology (LT). We also compared by simulations the performance of ns-2 and ns-3 considering memory size metric.**

***Keywords*: Ad-hoc networks; ns-3; ns-2; Linear Topology, Throughput.**

1. Introduction

Wireless ad hoc networks are collections of wireless nodes, that communicate directly over a common wireless channel. The nodes are equipped with wireless transceiver. They don't need any additional infrastructure, such as base station or wired access point, etc. Therefore, each node doesn't only plays the role of an end system, but also acts as a router, that sends packets to desired nodes. The ad hoc are expected to do assignments, which the infrastructure can't do. Ad hoc networks are mostly used by military, rescue mission team, taxi driver. Their works can't rely on a infrastructure's network. As an illustrative example, imagine firefighters put out hazardous fire in a big forest. They have to communicate each other, but establishing a infrastructure or cabling in such area is impossible or too expensive.

The main problems in ad hoc networks are routing and characteristic of wireless communication. In infrastructure's networks a node can communicate with all nodes in the same cell. In ad hoc a node can communicate only with nodes in its area. This node can communicate with other nodes, but a routing algorithm is necessary. Unlike wired communication, wireless networks have transmission problem with data transmission such as, possibility of asymmetric connections and higher interferences.

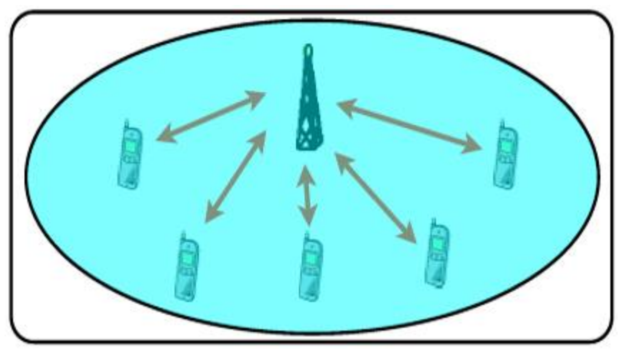


Fig. 1. Cellular network

2. Ad hoc networks

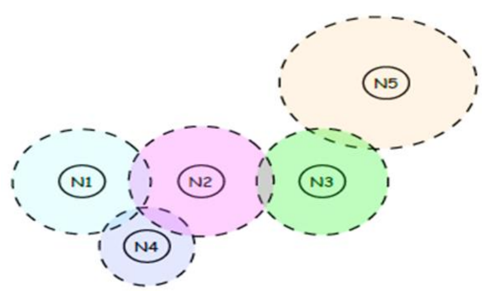


Fig. 2. Transmission area in ad hoc

The word ad hoc is from Latin and means "for this (only)". In the case of computer networks, the ad hoc networks mean wireless network without infrastructure, they can be called spontaneous network. One Way to understand ad hoc networks is by comparing them with infrastructure based wireless networks, such as cellular network and WLAN. In the infrastructure based wireless networks a node can only send a packet to a destination node only via access point (in cellular network like GSM, it is called base station). The access point establishes a network area and only the nodes in this area can use access point's services.

A. Architecture

The wireless networks can be categorized based on their system architecture into two basically version. The one is Infrastructure (Figure 3a) and second is ad-hoc network. The biggest different of them is infrastructure networks consist of access point and nodes, meanwhile the ad hoc networks are independent from access point.

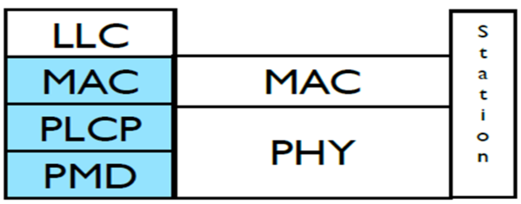


Fig. 3. Standard IEEE802.11 protocol architecture

1) IEEE 802.11 used for Ad Hoc Networks

The IEEE Standard 802.11 (IEEE, 1999) describes common family of wireless LANs. The standard specifies physical layer (PHY) and medium access control (MAC) of wireless transmission. The main purpose of this standard was the specification of simple and robust wireless LANs. The standard is expected to support the energy conservation of the mobile terminal, consideration of hidden terminal, and possibility of a global license-free service.

- *PHY layer*

802.11 supports 3 versions of physical layer. The one is infrared, and two others use radio transmission to transmit data (typically in 2,4 GHz). They are Frequency Hopping Spread Spectrum (FHSS) and Direct Sequence Spread Spectrum (DSSS). All of these versions provide Clear Assessment-(CCA-) signal and inform, if the medium is free. The physical layer also provides Service Access Point (SAP) with a data rate 1 or 2 Mbit/s.

- *MAC Layer*

MAC layer is responsible for many assignment. The most important assignment is obviously control the media access. This layer supports also roaming, authentication, and power management. The basic MAC layer's services are sported asynchronous data service and optional time-bounded service. The IEEE-Standard 802.11 for ad hoc provide only asynchronous data service.

B. Ad-hoc on-demand distance vector routing protocol (AODV)

AODV is a MANET routing protocol which employs an on-demand approach to find routes, that is, a route is discovered only when it is needed by a source station. AODV uses sequence numbers to make certain freshness of routes. AODV employs route request (RREQ) packets broadcasted through the group of connections to discover the paths needed by a source station. it allows stations to find routes very fast for new destinations, and does not need stations to store routes to destinations which are not moving. AODV aids stations to operate in response to an alteration in network topology and link breakages quickly and the AODV operation is loop-free

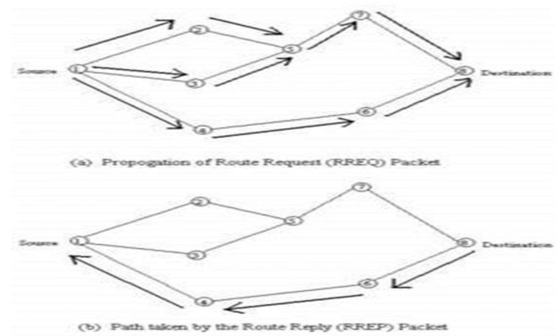


Fig. 4. Ad-hoc on-demand distance vector routing protocol

3. Wi-Fi hidden terminal and ad hoc grids

A. Wi-Fi Network

Wi-Fi is stands for wireless fidelity. Wi-Fi uses the 802.11 standard; it was developed by the Institute of Electrical and Electronics Engineers (IEEE) in 1997. Wi-Fi was superseded by the extensions 802.11a and 802.11b, and later by 802.11g. Wi-Fi technology uses radio communication and operating at a frequency of 2.4GHz.

1) Issues in Wi-Fi networks:

- Hidden Terminal Problem
- Exposed Terminal Problem

2) The Hidden Terminal Problem:

The hidden node/ terminal problem found at a point to multipoint network and it is defined as being one in which three or more nodes are present. Let there are three nodes: node A, node B and node C.

- A and C cannot hear each other.
- A sends to B, C cannot receive A.
- C wants to send B, C senses a free medium.
- Collision occurs at B.
- A cannot receive the collision.
- A is hidden for C.

The following figure-03 shows the Hidden Terminal Problem using node A, B and C

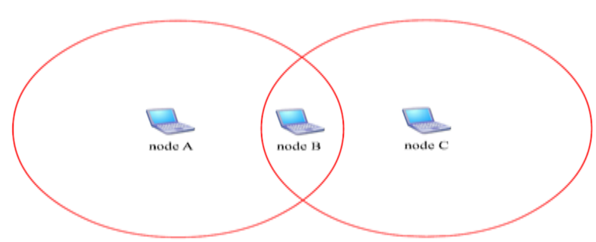


Fig. 5. Hidden terminal problem

3) Solution of hidden terminal problem

The solution of hidden terminal problem is as follows.

- When A wants to send a packet to B, A first sends a Request-to-send (RTS) to B.
- On receiving RTS, B responds by sending Clear-to-Send (CTS).
- When C overhears a CTS, it keeps quiet for the duration of the transfer.
- Transfer duration is included in both RTS and CTS.
- RTS and CTS are short frames, reduces collision chance.

B. The other methods that can be employed to solve hidden terminal problem are

- Increase Transmitting Power from the Nodes.
- Use unidirectional antennas.
- Remove obstacles.
- Move the node.
- Use protocol enhancement software.
- Use antenna diversity.

C. Effect of hidden terminal problem

If one node hidden to another then the re-transmission will increase. It also increases the delay and decrease the throughput.

4. Simulation code and results

Classical hidden terminal problem and its RTS/CTS solution.

Topology: [node 0] <-- -50 dB --> [node 1] <-- -50 dB --> [node 2]

This example illustrates the use of

- Wi-Fi in ad-hoc mode
- Matrix propagation loss model
- Use of On Off Application to generate CBR stream
- IP flow monitor

Run single 10 seconds experiment with enabled or disabled RTS/CTS mechanism

Create 3 nodes

- *Place nodes somehow, this is required by every wireless simulation*
- *Create propagation loss matrix*
- *Create & setup Wi-Fi channel*
- *Install wireless devices*
- *Install TCP/IP stack & assign IP addresses*
- *Install applications: two CBR streams each saturating the channel*
- *Install Flow Monitor on all nodes*
- *Run simulation for 10 seconds*
- *Print per flow statistics*
- *Cleanup*

5. Result

```
Hidden station experiment with RTS/CTS disabled:
Flow 1 (10.0.0.1 -> 10.0.0.2)
  Tx Packets: 2410
  Tx Bytes:   3441480
  TxOffered:  3.05909 Mbps
  Rx Packets: 184
  Rx Bytes:   262752
  Throughput: 0.233557 Mbps
Flow 2 (10.0.0.3 -> 10.0.0.2)
  Tx Packets: 2411
  Tx Bytes:   3442908
  TxOffered:  3.06036 Mbps
  Rx Packets: 267
  Rx Bytes:   381276
  Throughput: 0.338912 Mbps
------------------------------------------------
Hidden station experiment with RTS/CTS enabled:
Flow 1 (10.0.0.1 -> 10.0.0.2)
  Tx Packets: 2410
  Tx Bytes:   3441480
  TxOffered:  3.05909 Mbps
  Rx Packets: 480
  Rx Bytes:   685440
  Throughput: 0.60928 Mbps
Flow 2 (10.0.0.3 -> 10.0.0.2)
  Tx Packets: 2411
  Tx Bytes:   3442908
  TxOffered:  3.06036 Mbps
  Rx Packets: 577
```

1) Creating of 4 nodes

```
Hidden station experiment with RTS/CTS disabled:
Flow 1 (10.0.0.1 -> 10.0.0.2)
  Tx Packets: 3571
  Tx Bytes:   5099388
  TxOffered:  4.53279 Mbps
  Rx Packets: 430
  Rx Bytes:   614040
  Throughput: 0.545813 Mbps
Flow 2 (10.0.0.3 -> 10.0.0.2)
  Tx Packets: 2232
  Tx Bytes:   3187296
  TxOffered:  2.83315 Mbps
  Rx Packets: 82
  Rx Bytes:   117096
  Throughput: 0.104085 Mbps
Flow 3 (10.0.0.4 -> 10.0.0.2)
  Tx Packets: 1339
  Tx Bytes:   1912092
  TxOffered:  1.69964 Mbps
  Rx Packets: 19
  Rx Bytes:   27132
  Throughput: 0.0241173 Mbps
```

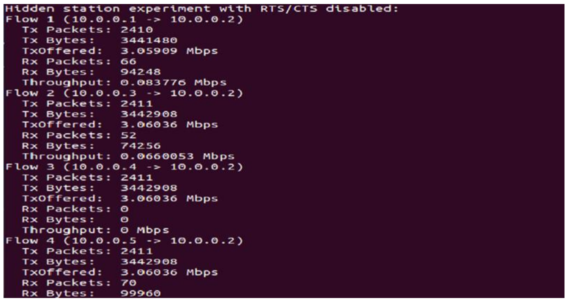
```
Hidden station experiment with RTS/CTS enabled:
Flow 1 (10.0.0.1 -> 10.0.0.2)
  Tx Packets: 3571
  Tx Bytes:   5099388
  TxOffered:  4.53279 Mbps
  Rx Packets: 559
  Rx Bytes:   798252
  Throughput: 0.709557 Mbps
Flow 2 (10.0.0.3 -> 10.0.0.2)
  Tx Packets: 2232
  Tx Bytes:   3187296
  TxOffered:  2.83315 Mbps
  Rx Packets: 247
  Rx Bytes:   352716
  Throughput: 0.313525 Mbps
Flow 3 (10.0.0.4 -> 10.0.0.2)
  Tx Packets: 1339
  Tx Bytes:   1912092
  TxOffered:  1.69964 Mbps
  Rx Packets: 126
  Rx Bytes:   179928
  Throughput: 0.159936 Mbps
```

2) Creating of 5 nodes

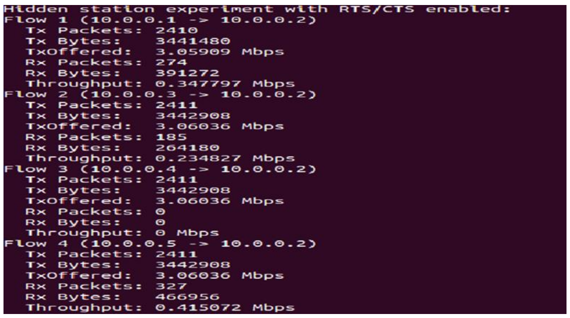
```
Hidden station experiment with RTS/CTS disabled:
Flow 1 (10.0.0.1 -> 10.0.0.2)
  Tx Packets: 2410
  Tx Bytes:   3441480
  TxOffered:  3.05909 Mbps
  Rx Packets: 15
  Rx Bytes:   21420
  Throughput: 0.01904 Mbps
Flow 2 (10.0.0.3 -> 10.0.0.2)
  Tx Packets: 2411
  Tx Bytes:   3442908
  TxOffered:  3.06036 Mbps
  Rx Packets: 16
  Rx Bytes:   22848
  Throughput: 0.0203093 Mbps
Flow 3 (10.0.0.4 -> 10.0.0.2)
  Tx Packets: 2411
  Tx Bytes:   3442908
  TxOffered:  3.06036 Mbps
  Rx Packets: 19
  Rx Bytes:   27132
  Throughput: 0.0241173 Mbps
Flow 4 (10.0.0.5 -> 10.0.0.2)
  Tx Packets: 2411
  Tx Bytes:   3442908
  TxOffered:  3.06036 Mbps
  Rx Packets: 26
  Rx Bytes:   37128
  Throughput: 0.0330027 Mbps
```

```
Hidden station experiment with RTS/CTS enabled:
Flow 1 (10.0.0.1 -> 10.0.0.2)
  Tx Packets: 2410
  Tx Bytes:   3441480
  TxOffered:  3.05909 Mbps
  Rx Packets: 332
  Rx Bytes:   474096
  Throughput: 0.421419 Mbps
Flow 2 (10.0.0.3 -> 10.0.0.2)
  Tx Packets: 2411
  Tx Bytes:   3442908
  TxOffered:  3.06036 Mbps
  Rx Packets: 326
  Rx Bytes:   465528
  Throughput: 0.413803 Mbps
Flow 3 (10.0.0.4 -> 10.0.0.2)
  Tx Packets: 2411
  Tx Bytes:   3442908
  TxOffered:  3.06036 Mbps
  Rx Packets: 239
  Rx Bytes:   341292
  Throughput: 0.303371 Mbps
Flow 4 (10.0.0.5 -> 10.0.0.2)
  Tx Packets: 2411
  Tx Bytes:   3442908
  TxOffered:  3.06036 Mbps
  Rx Packets: 132
  Rx Bytes:   188496
  Throughput: 0.167552 Mbps
```

3) Creating of 6 nodes

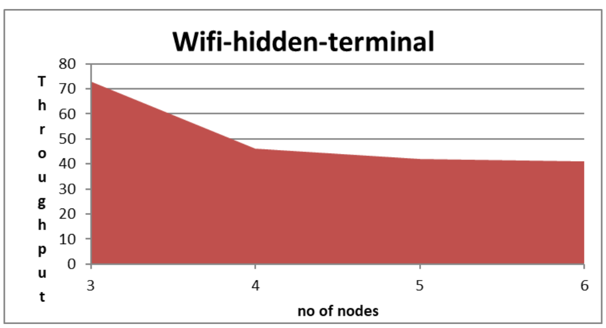


```
Hidden station experiment with RTS/CTS disabled:
Flow 1 (10.0.0.1 -> 10.0.0.2)
  Tx Packets: 2410
  Tx Bytes:   3441480
  TxOffered:  3.05909 Mbps
  Rx Packets: 66
  Rx Bytes:   94248
  Throughput: 0.083776 Mbps
Flow 2 (10.0.0.3 -> 10.0.0.2)
  Tx Packets: 2411
  Tx Bytes:   3442908
  TxOffered:  3.06036 Mbps
  Rx Packets: 52
  Rx Bytes:   74256
  Throughput: 0.0660053 Mbps
Flow 3 (10.0.0.4 -> 10.0.0.2)
  Tx Packets: 2411
  Tx Bytes:   3442908
  TxOffered:  3.06036 Mbps
  Rx Packets: 0
  Rx Bytes:   0
  Throughput: 0 Mbps
Flow 4 (10.0.0.5 -> 10.0.0.2)
  Tx Packets: 2411
  Tx Bytes:   3442908
  TxOffered:  3.06036 Mbps
  Rx Packets: 70
  Rx Bytes:   99960
```



```
Hidden station experiment with RTS/CTS enabled:
Flow 1 (10.0.0.1 -> 10.0.0.2)
  Tx Packets: 2410
  Tx Bytes:   3441480
  TxOffered:  3.05909 Mbps
  Rx Packets: 274
  Rx Bytes:   391272
  Throughput: 0.347797 Mbps
Flow 2 (10.0.0.3 -> 10.0.0.2)
  Tx Packets: 2411
  Tx Bytes:   3442908
  TxOffered:  3.06036 Mbps
  Rx Packets: 185
  Rx Bytes:   264180
  Throughput: 0.234827 Mbps
Flow 3 (10.0.0.4 -> 10.0.0.2)
  Tx Packets: 2411
  Tx Bytes:   3442908
  TxOffered:  3.06036 Mbps
  Rx Packets: 0
  Rx Bytes:   0
  Throughput: 0 Mbps
Flow 4 (10.0.0.5 -> 10.0.0.2)
  Tx Packets: 2411
  Tx Bytes:   3442908
  TxOffered:  3.06036 Mbps
  Rx Packets: 327
  Rx Bytes:   466956
  Throughput: 0.415072 Mbps
```

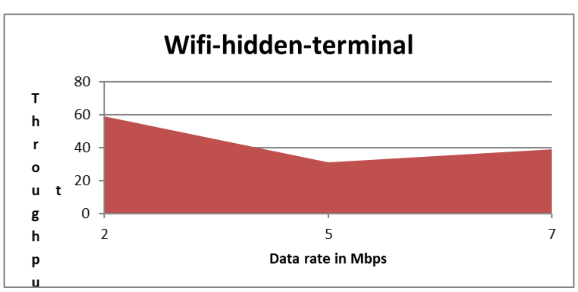
Graphs:
No. of Nodes vs. Throughput



Nodes vs. throughput"

The above graph illustrates that as the number of nodes increases the throughput gradually decreases. As theoretically we know that through put (efficiency) is inversely proportional to the number of nodes present in the network. Practically observed in the above graph. As the nodes increases in the network traffic increases.

Data rate vs Throughput:



Data rate vs. throughput:

Theoretically we know that as the data rate is increases throughput decreases because the speed of the source is more than the speed of the destination the packet drops are more. As the data rate is less for the destination it cannot handle the packets which are from the source so they are dropped. By this the efficiency decreases gradually as shown in the graph.

6. Conclusion

Mobility in the wireless networks is very popular nowadays. Many peoples in the street walk and are using small devices like PDA, laptops, or phone to communicate, listening a music, write SMS, exchanging data with other people near them, etc. The wireless infrastructure networks support great mobility and very popular among the folks. But this kind of networks is centralized, not flexible, and sometimes too expensive. If a infrastructure is defect, the cell established by this infrastructure will be gone too. The nodes in this cell can't communicate again. The presence of ad hoc networks covers the infrastructure's weakness. Since the ad hoc networks are independent from infrastructure, the nodes must be able to work together to establish a greater network. They have multi hop the packet, if they have to send a packet to a destination node outside their transmission range.

Therefore, routing algorithms are the main challenge. Since the nodes are mobile, link between nodes are not symmetric, and the topology are always changed, the routing algorithms used in wired network must be modified or must be invented. The ad hoc networks still have to deal with wireless problems, such as security and higher error rate. Especially WANETs have to consider their power supply, since they are not supported with fixed power supply. At least, the ad hoc networks are developed not to replace the infrastructure networks. With the great number of wireless user and frequency limitations, it is unlikely possible to control independent network. The ad hoc networks can replace the infrastructure networks only for a short time and are used for some specific situation, in which the infrastructure networks fail. A combination of both networks like figure 13 can offer great output, like connection between ad hoc and Internet.

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