Performance Analysis of Wireless Mesh Network in Hospital Environment

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ABSTRACT

In Wireless Mesh Network (WMN), the communications are made up of radio nodes which are organized in a mesh topology. In this paper, an analyze is made for the existing network at the Aravind eye hospital in Theni, in order to deploy WMN in the existing network to overcome the node failure, frequent maintenance of the nodes and failure of the link between the nodes. The hospital network consists of five rural vision centres connected to the main hospital. The routing between the nodes is done by using Hybrid Wireless Mesh Protocol (HWMP) routing protocol. The performance analysis of the WMN in this hospital environment is evaluated by using various parameters in order to support video conferencing for rural patients.

Keywords

Wireless mesh network, hybrid wireless mesh protocol, route request and route reply

1. INTRODUCTION

Wireless mesh network (WMN) is a communication network which provides multi-hop communication over wireless links which increases the effective coverage area. The coverage area of the radio nodes works as a single network. So it is sometimes called a mesh cloud. Access to this mesh cloud is dependent on the radio nodes working in harmony with each other to create a radio network. WMNs can provide ubiquitous network connectivity at lower cost and in areas not usually capable of wired connectivity. Today WMNs are widely known for-runner of wireless multi-hop networking and network deployment. In WMNs, each node operates not only as a host but also as a router; user packets are forwarded to and from an internet-connected gateway in a multi-hop fashion. Some of the attractive features of WMNs are dynamically self-organized, self-configuration, self-healing, easy maintenance, high scalability and reliable services [1].

In a WMN, the wireless link becomes a part of the infrastructure over which packets are forwarded, relayed and routed. In order to improve the capacity of WMNs and for supporting the traffic demands raised by emerging applications for WMNs, multi radio WMNs (MR-WMNs) are under intense research [2]. Therefore, recent advances in WMNs are mainly based on a multi radio approach. While MR-WMNs promise higher capacity compared with single-radio WMNs but it is facing many challenges. Several emerging and commercially interesting applications for commodity networks based on WMN architecture have been deployed recently. These include intelligent transportation system and residential broadband access for hard to reach and scarcely populated areas. The primary advantages of a WMN are inherent fault tolerance against network failures, simplicity of setting up a network, and the broadband capability [3]. The WMNs provide a reliable and cost effective solution to extending coverage in a rural fixed network. The mesh topology provides an excellent solution for last mile connectivity in difficult terrain like the Aravind eye hospital network at Theni located in southern India.

The rest of the paper is organized as follows. In section 2, hospital environment network is described. Section 3 explains WLAN mesh network. Section 4 evaluates the performance through simulation configuration and discusses the results in detail. The paper is concluded in section 5.

2. HOSPITAL ENVIRONMENT NETWORK

In the Aravind hospital environment network at Theni consists of five vision centres which are connected to the main hospital (Fig.1) [4]. The Aravind network uses WI-Fi based long distance network [5] to interconnect rural vision centres with their main hospitals for patient-doctor video conferencing. The network has a total of 11 wireless routers (6 endpoints, 5 relay nodes) and uses 9 point-to-point links [6]. The links range from 1km (Theni - Vijerani) to 15km (Vijerani - Andipatti). The six wireless nodes are installed on towers in heights range from 24-42m. The remaining are used as short poles on rooftops or existing tall structures, such as the chimney of a power plant on the premises of a textile factory. Currently 9 vision centres cater to 3000 patients per month. Thus, nearly 30,000 rural patients have been examined and 3000 have had significant vision improvement.

2.1 Components are More Inclined to Fail

The operating conditions in the Aravind network have greatly contributed to a substantial decrease in the robustness of system components that would otherwise work quite reliably. One major bottleneck has been the lack of stability and quality power. Although issues such as frequent power outages in rural areas are well known, there is a high degree of power quality problems in rural villages even when power is available. Low voltages leave routers in a wedged state, unable to boot completely. Fluctuating voltages because frequent reboots, which corrupt and occasionally damage the routers. Lightning strikes may often damage the radios. Lack of quality power increases not only downtime but also maintenance costs. Travelling to remote relay locations just to reboot the node or replace the flash memory is expensive.

2.2 Fault Diagnosis is Difficult

Accurate diagnosis of the problem can greatly reduce response time and thus downtime. The most common description of a fault by our rural partners is that the *link is down*. There are a wide variety of reasons for network outages and it is not always easy to diagnose the root cause [6]. The lack of appropriate tools for inexperienced staff, combined with unreliable connectivity which hinders detailed monitoring, prevents accurate diagnosis. For example, a remote host might be running properly, yet is unreachable when an intermediate wireless link goes down. Sometimes local misunderstandings equipment usages make it even harder to diagnose problems.

Fig.1: Satellite Map of Aravind Eye Hospital Network

2.3 Anticipating Faults is Hard

Some of the node locations in the network, especially relays, are quite remote. Site maintenance visits are expensive, time consuming, and require careful planning around the availability of staff, tools, and other spare equipment Therefore, visits are generally scheduled well in advance, typically once every six months. In this scenario, it is especially important to be able to anticipate failures so that they can be addressed during the scheduled visits.

3. WLAN MESH NETWORK

IEEE 802.11s started with a charter to extend WLAN for extended service set (ESS) mesh networking. An 802.11 ESS consists of multiple basic service sets(BSSs) connected through a distributed system(DS) and integrated with wired LANs .The DS service (DSS) is provided by the DS for transporting MAC service data units (MSDUs) between access points(APs), between APs and portals, and between stations(STAs) within the same BSS that choose to involve DSS. The 802.11 standard has pointed out the difference between independent basic service set (IBSS) and ESS. IBSS actually has one BSS and does not contain a portal or an integrated wired LANs since no physical DS is available. Based on such a concept, the network architecture of 802.11s is illustrated in Fig. 2. Existing IEEE 802.11 standards specify WLAN access network operations between WLAN clients STAs and APs [7]. In order to extend IEEE 802.11 standards for mesh, backhaul (infrastructure WLAN links) and gateway (infrastructure WLAN to wired-LAN links) operations must be amended to the existing standards. These operations are in the areas of medium access control (MAC), power saving, routing and forwarding, interworking with 802 other networks, security, and quality of service (QoS), management and configuration of a WLAN mesh network. A WLAN mesh network is a fully IEEE 802.11-based wireless network that employs multi hop communications to forward traffic en route to and from wired Internet entry points. The WLAN mesh network uses 802.11-based physical layer (PHY) device and medium access (MAC) for providing the functionality of an ESS mesh network. The 802.11 AP (known as a mesh point [MP] when used in WLAN mesh) establishes wireless links among each other to enable automatic topology learning and dynamic path configuration [8-9]. The MP-to-MP links form a wireless backbone known as mesh backhaul, which provides users with low-cost, high-bandwidth, and seamless multi hop interconnection services with a limited number of Internet entry points and with other users within the network. Each MP may optionally provide wireless access connections to users known as mesh access. These devices are called Mesh access points (MAPs) [10]. A WLAN mesh may support zero or more entry points (mesh portals [MPPs]), automatic topology learning, and dynamic path selection (including across multiple hops).

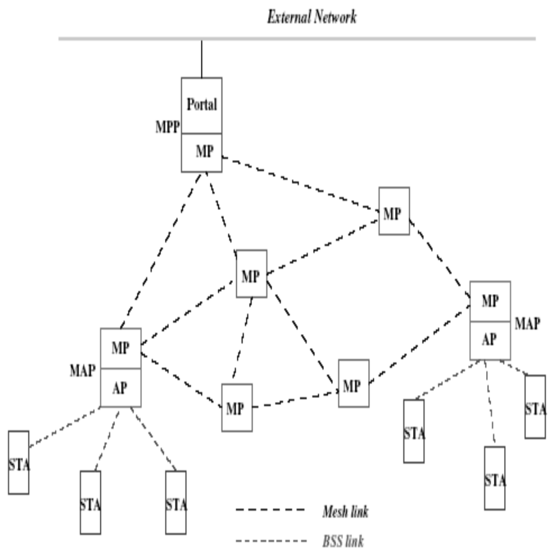

Fig.2: Network architecture of 802.11s meshed wireless LANs

3.1 WLAN Mesh Routing Protocol

HWMP is the default protocol for IEEE 802.11s WMN. This protocol utilizes layer 2 addressing; therefore IEEE 802.11s denotes it as path selection protocol instead of routing protocol. The Hybrid protocol refers to the fact that it supports both Reactive and Proactive routing. HWMP utilizes the features of a reactive AODV routing protocol called radio-metric AODV (RM-RMAODV). HWMP supports two modes of operation depending on the configuration. The two modes are described as below.

3.1.1 On Demand mode

In this mode, it allows MPs to communicate using peer-to-peer path. This mode is used in situations where there is no root MP configured. If no root portal is configured, then the RM-AODV is used for path selection. For destinations within the mesh the route discovery works like normal AODV. If the destination is outside the mesh, the source receives the number RREP upon a RREQ. Therefore it sends the messages to the route portal after a timeout. The portal forwards them to the connected network.

3.1.2 Proactive Mode

The route is discovered before any request or demand and as a result when the request arrived for a particular destination node it is fulfilled. Root Portals are configured to send announcement called the root announcement (RANN) periodically. The root MP periodically floods a RANN message into the network. The information contained in the RANN is used to disseminate path metrics to the root MP. Upon reception of a RANN, each MP that has to create or refresh a path to the root MP sends a unicast *path request* (PREQ) to the root MP via the MP from which it received the RANN. The unicast PREQ follows the same processing rules defined in the on demand mode [11].

The root MP sends *path reply* PREP in response to each PREQ. The unicast PREQ creates the reverse path from the root MP to the originating MP, while the PREP creates the forward path from the MP to the root MP. When the path from an MP to a root MP changes, it may send a PREP with the addresses of the MPs that have established a path to the root MP through the current MP. The mesh portal connects mesh networks to outside network like internet [12]. A designated mesh portal (MPP) is selected as designated root MPP. This selection is done either by configuration or by selection process. As a result the tree structure with a root and it allows proactive routing towards MPP. Fig.3 shows the process of HWMP route discovery.

4. THE SIMULATION CONFIGURATION AND RESULTS

In the section, the simulation test bed scenario in meters similar to Aravind eye hospital network is created in Qualnet 4.5. There are 10 nodes acting as MPs which are uniformly placed at a distance from each other. These nodes are establishing WMNs connections with each other. All nodes are mesh routers and node 4 acts as a central mesh router that could be connected to a wired network. IEEE 802.11g radio is used by all the nodes. Each node has a 6Mbps link. HWMP is used for routing purpose. Airtime link metrics are used as the default metrics. Fig.4 shows MPs uniformly placed in Qualnet and Fig.5 shows the mesh link establishment of all nodes.

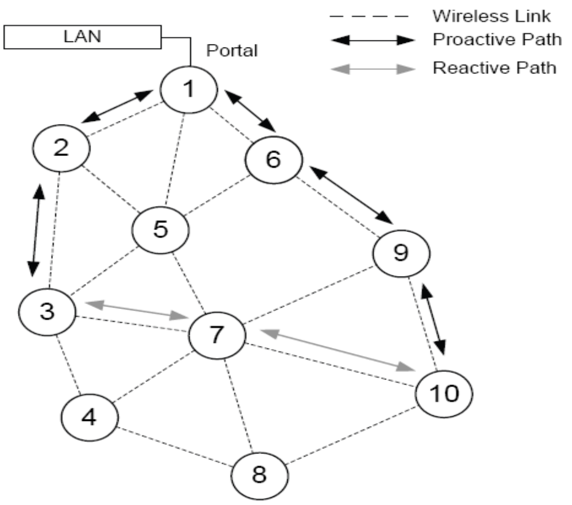

Fig.3: HWMP route discoveries

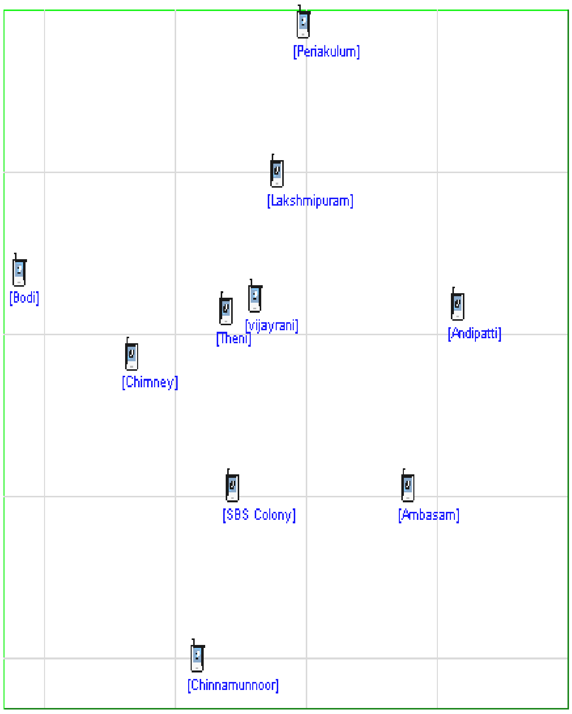

Fig.4: Mesh points uniformly placed in Qualnet

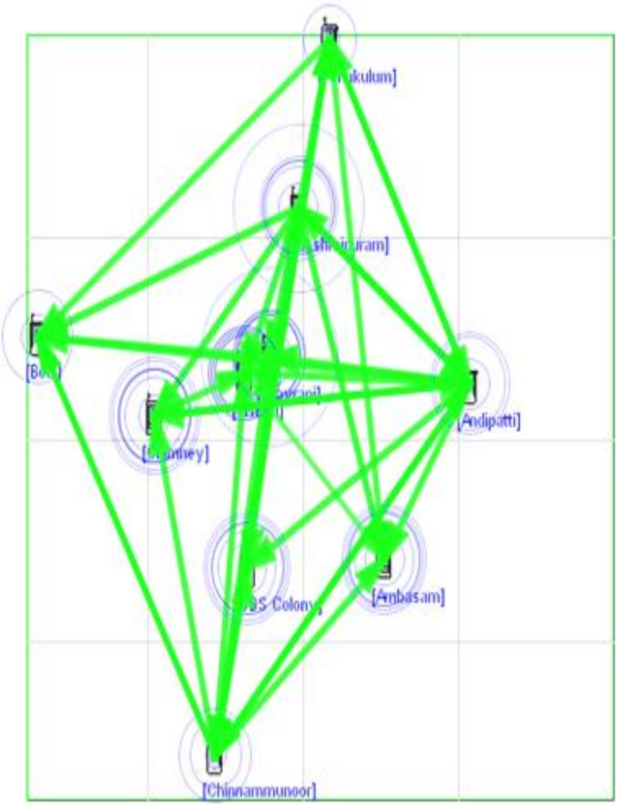

Fig.5: Mesh link establishment of all nodes

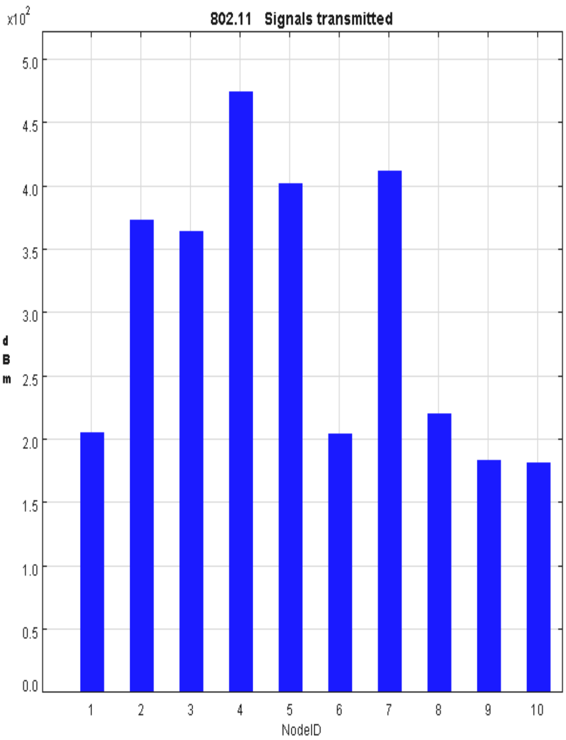

Fig.6: Signals transmitted from each node in dBm

Fig.6 represents the signal transmitted from each node. Table.1indicates the Node ID of the places. For example node ID 1 represents the periakulum and node ID 4 represents the theni. From the figure, It shows that node 4 transmit more signals then the other nodes. The signal transmitted from node 9 an 10 is lesser due to the distance from node 4 to the nodes is much longer then other nodes. The value of the signals transmitted from each node is based on the establishment of mesh between the nodes and the distance with respect to node 4. Table.2 represents the signal transmitted from each node

Table 1. Node Id representing the places

Node ID	Signal Transmitted (dBm)
1	205
2	373
3	363
4	474
5	402
6	204
7	412
8	220
9	183
10	181

Fig.7 shows the variation of data throughput with each node which acting as a server or destination. For video conferencing purpose CBR is used. The bit rate is fixed as 5 Mbps. Here except node 4 all other nodes act as a client or source node. Node 2, 3, 4, 5 and 7 act as a destination server node. Data Throughput is the average total number of data bytes received by the destination over the total simulation time. Here node 4 has the maximum throughput since it receives data from many nodes.

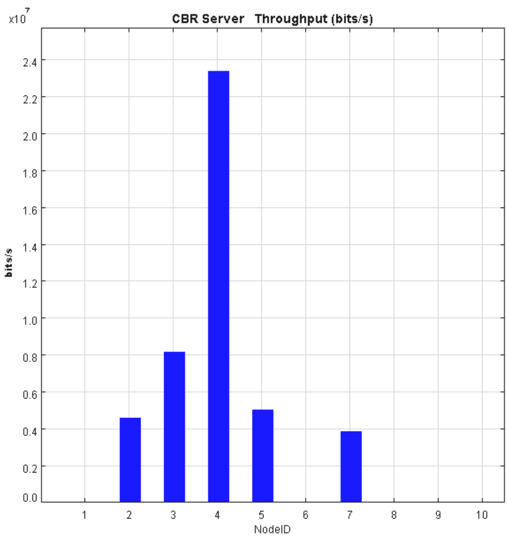

Fig.7: CBR server throughputs

Fig.8 shows the average end to end delay of the destination nodes. In general, the Average end to end delay is the average elapsed time to deliver a packet from the source to the destination. It includes all the delays that occur from source to destination. Node 4 acts as a main destination or server node. It can be seen that node 4 (theni) has the maximum end to end delay since it receives packets from all other nodes. Node 2 receives packets only from node 1. Similarly node 7 receives a packet from only from node 8.

Table 2. Signal transmitted from each node

Node Id	Place
1	Periakulun
2	Laksmipuram
3	Vijayrani
4	Theni
5	Chimney
6	Bodi
7	SBS Colony
8	Chinnamunnoor
9	Ambasam
10	Andipatti

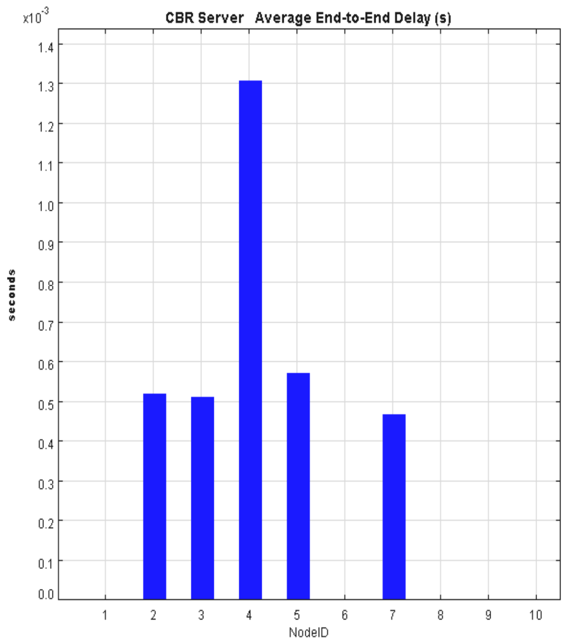

Fig.8: Average end to end delays from each node in seconds

Fig.9 shows the average jitter present in the destination nodes. Node 3 (Vijayrani) has the maximum jitter due to more congestion in that node. Node 3 receives packets from nodes 2,4,7,9 and 10 and hence the congestion is more in that node.

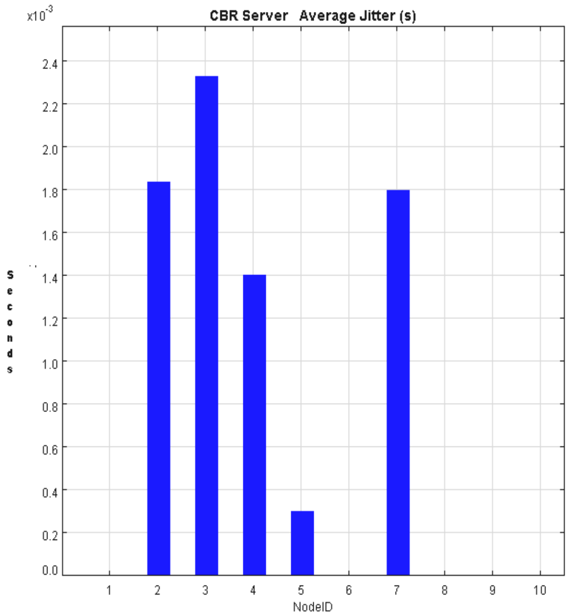

Fig.9: Average jitter from each node in seconds

Fig.10 and 11 represents the total number of RREQ and RREP Messages received from the node. Node 4 receives more no of RREQ messages to establish the routing with other nodes. Node 7 receives a number of RREP messages from another node. The node 4 act as the destination for other node it does not receive any RREP messages. Based on number of RREQ and RREP received by each node the best path is selected to the destination node 4.

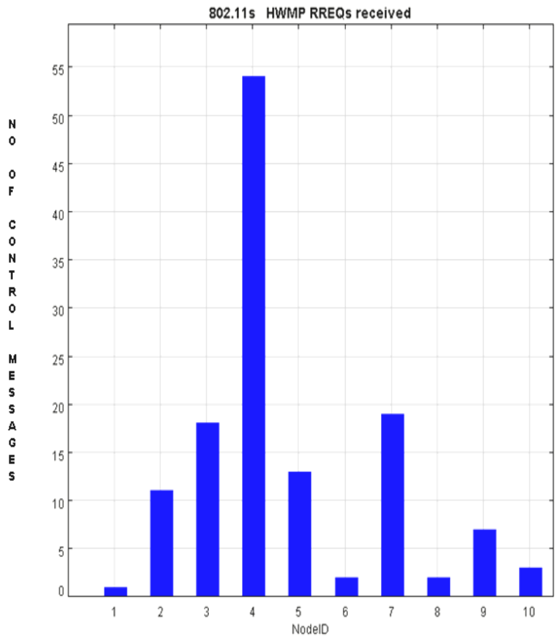

Fig.10: Total no of RREQs messages received from each node

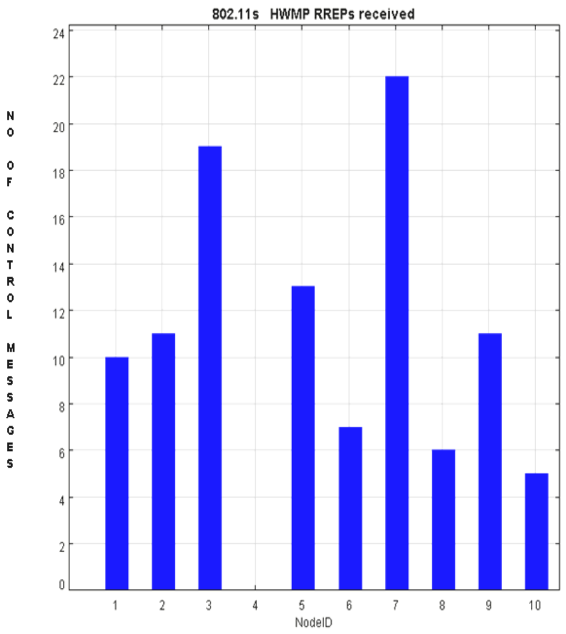

Fig.11: Total no of RREPs received from each node

5. CONCLUSIONS

In this paper, a scenario similar to the Aravind eye hospital network is created and investigated in Qualnet for video conferencing purpose. For the routing purpose, HWMP is deployed and it is used for both reactive and proactive routing. The routing is done by using control messages namely, RREQ and RREP. In this simulation scenario, the number of RREQ and RREP messages received by each node is also analysed for selection of the best path. The parameters are evaluated from the analysed results, it is identified that throughput and end to end delay is maximum for Theni node and average jitter is maximum for the Vijayrani node due to more congestion. Further investigations are under study to enhance the performance.

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