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DATA COLLECTION THROUGH ADAPTIVE CLUSTER HEAD SELECTION SCHEMEIN WIRELESS BODY AREA NETWORKS

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Abstract - Due to the development in the field of Wireless Sensor Networks (WSNs), its major application, Wireless Body Area Network (WBAN) haspresently become a major area of interest for the developers and researchers. Efficient data collection is the key feature of any effective wireless body area network. Prioritizing nodes and cluster head selection schemes plays an important role in WBAN. Human body exhibits postural mobility which affects distances and connections between different sensor nodes. In this context, we propose maximum consensus based cluster head selection scheme, which allows cluster head selection by using Link State. Nodal priority through transmission poweris also introduced to make WBAN more effective. This scheme results in reduced mean power consumption and also reduces network delay. A comparison with IEEE 802.15.6 based CSMA/CA protocol with different locations of cluster headis presented in this paper. These results show that our proposed scheme outperforms IEEE 802.15.6 based CSMA/CA protocol in terms of mean power consumption, network delay, network throughput and network bandwidth efficiency.

Keywords - WBAN, CSMA/CA, LST, Adaptive Cluster head, Nodal Priority

I. INTRODUCTION

A wireless sensor network (WSN) consistsof sensor nodes to examine and monitor the environmental factors such as temperature, sound etc. and send their data to the base station as discussed in [1], [2], [3].Wireless Body Area Network (WBAN) is a special application of WSN to monitor things remotely. A WBAN is a special purpose sensor network which is developed to manage and communicate between various medical sensors, which are positioned inside and outside the human body [4]. A special example of WBAN is presented in Figure 1.In tier 1, these sensors, sense body temperature, heart beat rate, pulse rate and other required data and send it to personal coordinator through ZigBee or Bluetooth. The personal server or personal coordinator in tier 2 send these values to medical server through internet. The health care provider (doctor) sitting in tier 3 examines the results and gives precautions and medical treatments to the patient [5]

Human beings generally change their postures as shown in Figure 2. As the human body moves, the wireless connectivity amongst the nodes also varies. In this situation, the data cluster head has to be changed and adjusted as distance between sensor nodes varies. Another thing, which is very important for a cluster head is its accessibility by all neighboring nodes. This would ensure that each node sends its data to the cluster head, which will ultimately increase the reliability of WBAN.

Our proposed scheme is called Adaptive Cluster HeadSelectionSchemewith Nodal Priority for wireless body area networks, in which we are selecting a cluster head on the basis of link state. We have used Omnet++ with Mixim framework, which makes simulation, more realistic and reliable [6]. MoBAN mobility model, which is discussed in [7] is also used to establish postures for human body.

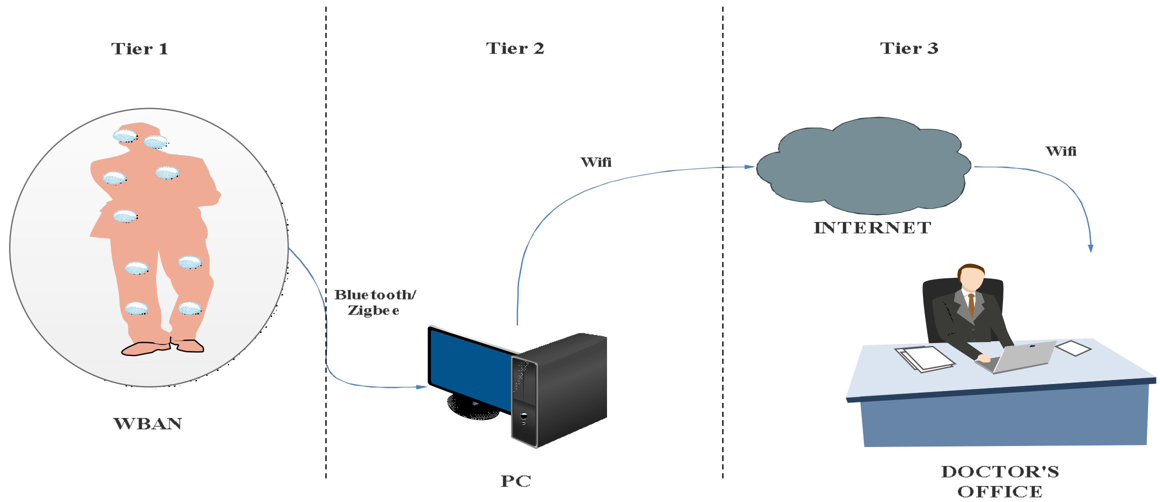

Figure 1. Wireless Body Area Network

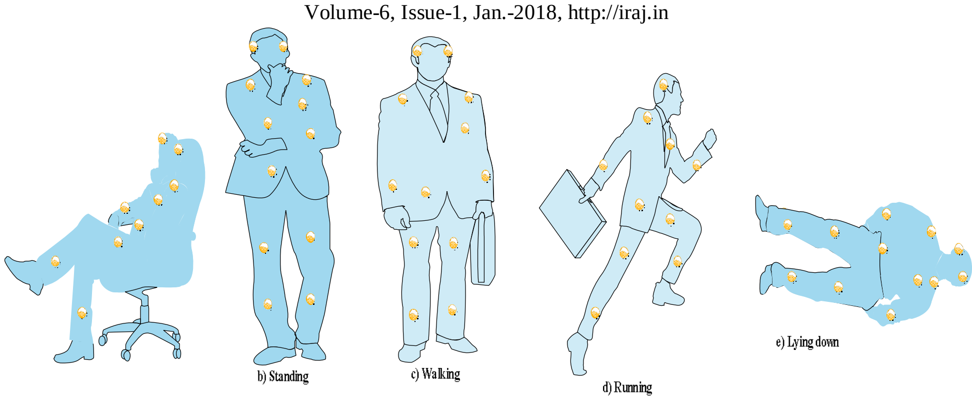

Figure 2. Human Body Postures

The rest of the paper is organized as follows: In section 2, related work is discussed, motivation is presented in Section 3, proposed scheme is described in Section 4, performance parameters are discussed in Section 5, Section 6 containsresults and analysis, and we conclude our findings in Section 7.

II. RELATED WORK

A lot of work has been done in the field of wireless body area networks.Our work also comprises of using the proper MAC scheme for assigning nodal priority. Thecommonly used MAC layer protocols include S-MAC, B-MAC, LMAC, Wise MAC and IEEE 802.15.6 based CSMA/CA Protocol.

Sensor MACprotocol is one of the energy efficient MACprotocols. According to[8] ,SMAC reduces energy consumption by avoiding collisions, idle listening ,overhearing, and minimizing control packet overheads. Periodic sleeping is an integral working component of SMAC, and according to conditions a node will go to sleep state if there is no data transmission or reception. During the sleep state, the node turns its radio off, and sets a timer for switching to awake status later

B-MAC commonly called Berkeley MAC protocol is LPL (Low power listening) based protocol discussed in [9].Its objective is to assign greater sleep intervals to nodes for optimum network lifetime and waking up after regular intervals to check for ongoing data communication.

Lightweight Medium Access protocol also known as LMAC is TDMA based protocol. According to [10], [11], LMAC network is self-organizing in terms of slot assignment and synchronization.

Wise MACis also an energy efficient MACprotocol, which is defined in [12], [13]. Wise MACis based upon non persistent CSMA and reduces power consumption by using preamble sampling and by reducing idle listening.

MAClayer protocol, which we chose to enhance is IEEE 802.15.6 based CSMA/CA protocol. In CSMA/CA the node detects the channel for idleness, if the channel is idle, then node will broadcast the data through the channel and if channel is busy, node will wait for random time and will try again [14]. In IEEE 802.15.6 based CSMA/CA Protocol, the node sets a back off counter between 1 and contention window size. If the channel is idle, the node will decrement the back off counter by one for each idle CSMA slots. And when the back off counter becomes zero, the node will transmit the data or frame. If the channel is found busy, the node will lock its back off counter until the channel becomes idle. Here in [15], another counter which counts the number of failures is presented. Two cases are presented here, the first one in which number of failures is odd, then Contention Window (CW) size will remain unchanged and if the number of failures is even, then CW size will be doubled. After successful data transmission, CW is set to initial CW.

III. MOTIVATION

Main objective of proposed scheme is to make WBAN more reliable and energy efficient by introducing idea of acknowledgement and adaptive cluster head selection in CSMA/CA protocol.

By introducing acknowledgements, we can ensure that the two nodes are connected and data transmission is taking place successfully. There is no such mechanism in IEEE 802.15.6 based CSMA/CA protocol. Another approach that we have introducedis the idea ofadaptive cluster head selection with nodal priority in CSMA/CA protocol which reduces data loss and also increases network throughput thus ultimately making CSMA/CA more efficient and effective.

IV. PROPOSED SCHEME

Easily accessible cluster head for data packets is very important for wireless body area network. As we know that in WBAN, distances and connectivity between different nodes vary according to the posture, as shown in Figure 3 and Figure 4. Using fixed cluster head has no significance because other nodes may or may not access that particular node. So, it is required to use cluster head which keeps changing throughout network lifetime. Routing table is commonly used to select a random cluster head for data packets, as done in Omnet++/Mixim, but depending on the routing table only is not a very effective technique. The reason is that a random cluster head may or may not be accessible by other nodes, which will ultimately create problems in WBAN, because information from every node will help doctors to treat patient in an effective way. So, information gathering from every node is the key feature of an effective WBAN.

In such situation, adaptive cluster head for data packets, which keeps changing depending upon the number of connections that each node holdsthus contributing to enhance performance of the overall network. Introducing priority for nodes will further make this scheme more efficient.So, we propose adaptive cluster head selection with nodal priority. Explanation of our proposed scheme is done in this section.

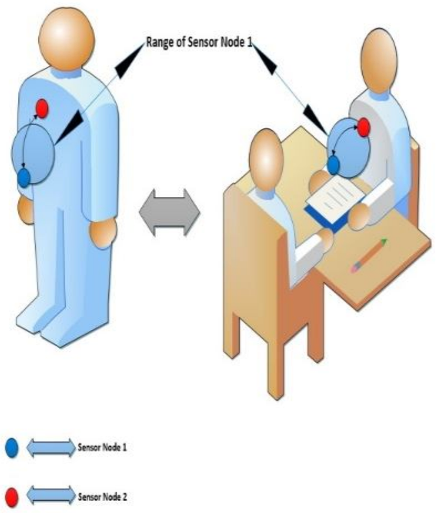

Figure3.Illustration of Range Changing of Sensor Nodes with Postural Changes

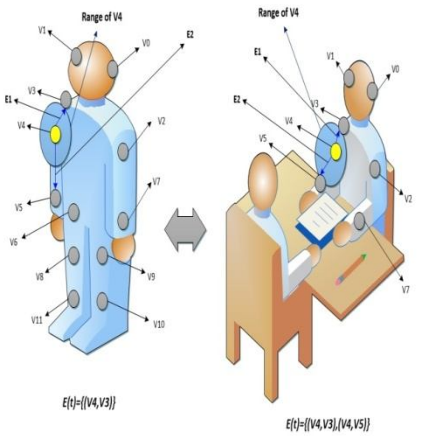

Figure 4. Illustration of Variation in No. of Connections with Postural changes

Link state table is a very important feature of our scheme. This table contains information about number of connections that each node holds. This table is maintained at each node. The complete procedure for updating this table and selecting adaptive cluster head on the basis of LST is illustrated through flow chart in Figure 5.

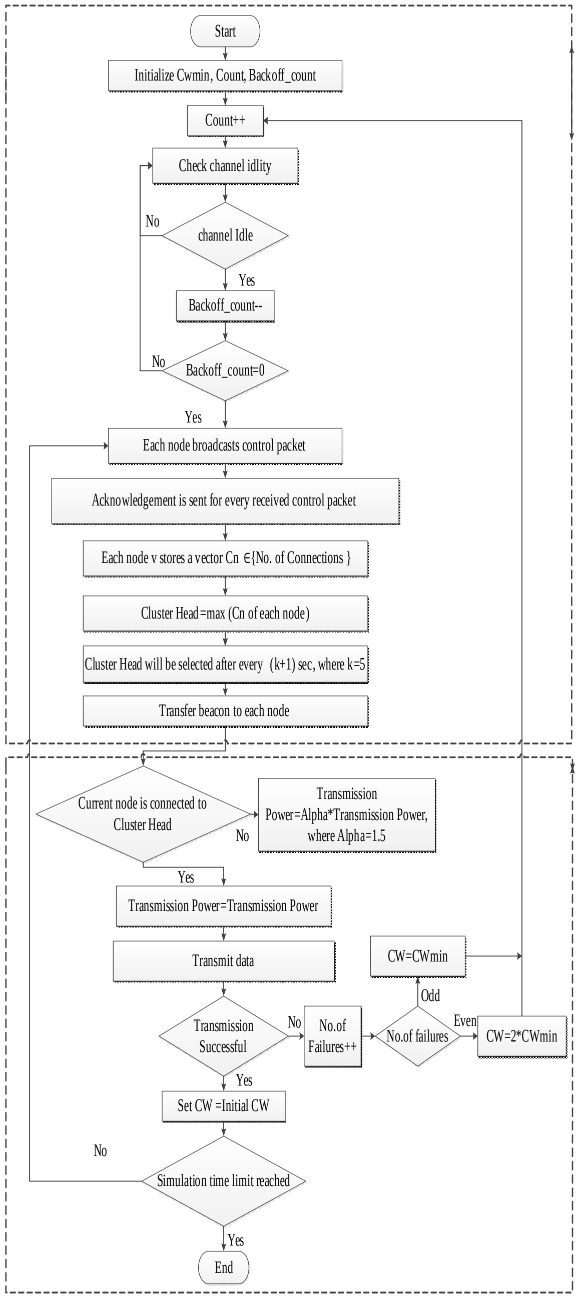

Figure 5. Flow Chart of Proposed Scheme

According to Figure 5, after initializing important parameters like CWmin count, backoff_count, channel idleness will be checked, if idle, then backoff_count will be decremented until it becomes zero. Consequently, each node will broadcast control packet, upon the reception of control packets from other nodes, each node will acknowledge the sender that the control packet has been received. Link State Table (LST) will be updated (Incrementing No. of Links) after reception of acknowledgement otherwise it will remain unchanged. The nodehaving maximum value in LST shows that it has maximum number of connections as compared to other nodes for current posture. So, there will be a competition between all sensors nodes to become “Cluster Head” on the basis of value stored in their LST. Node with maximum value in LST will become cluster head for other nodes. Power of those nodes which are not directly connected to the cluster head, will be increased, so that, each node can send its data to the cluster head. After that, data will be transmitted, if transmission is not successful, then number of failures will be counted, if odd, then contention window will remain same otherwise it will be doubled. The reason is that even number of failures would confirm that there is a problem in contention window, which stops transmission. A simple example for cluster head selection is given in figure 6. According to Figure 6, at time t_{k+1}, node 5, will become cluster head node because of holding maximum no. of connections. At t_{k+21}, node 3, will become cluster head.

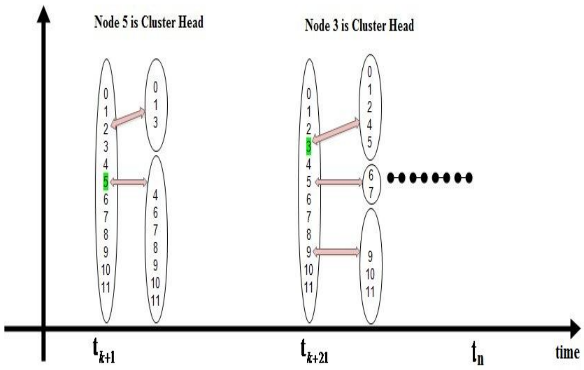

Figure 6. Example Related To Flow Chart

V. PERFORMANCE PARAMETERS

Important notations and parameters list is given in Table 1 and Table 2 respectively. User priority list is presented in Table 3.

T_p	Preamble transmission time
R_s	Preamble transmission symbol rate
T_{PHY}	PHY layer header transmission time
R_{hdr}	Header rate of PHY layer
R_{DATA}	Transmission rate of data
T_s	Slot length
T_{pSIFS}	Short inter-frame spacing time
T_{pMIFS}	Minimum inter-frame spacing time
MHR	Mac header
FTR	Mac footer
τ	Propagation time
n'	Frames transmitted in single burst
x	Payload Size

Table 1. Notations used in calculation

PARAMETER NAME	VALUE
Saturation	-90 dB_m
Alpha	3
Carrier frequency	2.412 GHz
Time R_x to T_x	0.00021s
Time R_x to Sleep	0.000031s
Time T_x to R_x	0.00012s
Time T_x to Sleep	0.000032s
Time Sleep to R_x	0.000102s
Time Sleep to T_x	0.000203s
T_{pMIFS}	20 μs
T_{pSIFS}	50 μs
T_p	88bit/ R_s
τ	1 μs
T_{PHY}	31bits/ R_{hdr}
Queue Length	5
Slot Duration	0.00035s
Max T_x Attempts	14
Bit Rate	200000 bps
Contention Window/ CW_{min}	16
T_x Power	100 mW
MHR	56
FTR	16
R_s	187500
R_{hdr}	57500
Pdelay	0.000001
x	2000

Table 2. Simulation parameters

User	Transmission Power (mW)	Priority
0	1	1st
1	0.96	2nd
2	0.92	3rd
3	0.88	4th
4	0.84	5th
5	0.80	6th
6	0.76	7th
7	0.72	8th
8	0.68	9th
9	0.64	10th
10	0.60	11th
11	0.56	12th

Table 3. Priority List

Mathematical formulae used to calculate delay, throughput and bandwidth efficiency are given below. Formula to calculate delay normally, is given below;

$$Delay(x) = T_{avg\_backoff} + T_{DATA} + T_{I-ACK} + 2T_{pSIFS} + 2\tau$$
(1)

The average back off time can be found as;

$$T_{avg\_backoff} = \frac{CW_{\min} \cdot T_s}{2} \quad (2)$$

The transmission time of data is T_{DATA} and can be obtained as;

$$T_{DATA} = T_p + T_{PHY} + \frac{(MHR + x + FTR)}{R_{DATA}} \quad (3)$$

The transmission time of immediate acknowledgement can be obtained as;

$$T_{I-ACK} = T_P + T_{PHY} + \frac{(MHR + FTR)}{R_{DATA}} \quad (4)$$

Maximum throughput (MT) of network is directly related to overhead.

The MT is defined as the ratio of payload size (x) to the total transmission delay per payload size Delay(x), as given below [7];

$$MT = \frac{x}{Delay(x)} \quad (5)$$

Maximum throughput (MT) in case of immediate acknowledgement as in [3];

$$MT_{I-ACK} = \frac{x}{(T_{avg\_backoff} + T_{DATA} + T_{I-ACK} + 2T_{pSIFS} +}$$
(6)

The bandwidth efficiency is inversely proportional to the basic data rate;

$$\rho = \frac{MT}{R_{DATA}} \quad (7)$$

VI. PERFORMANCE ANALYSIS

Mobile Network Performance Analysis:

Figure 7 shows delay versus time comparison between fixed cluster head, random cluster head selection scheme, adaptive cluster head selection scheme and adaptive cluster head selection scheme with priority for mobile network. In these results, lower delay is achieved in adaptive cluster head selection scheme with priority.

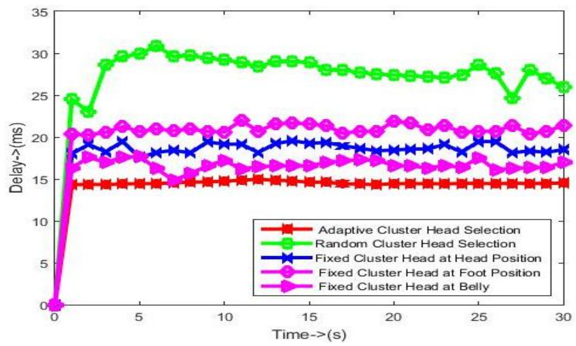

Figure 7. Mobile Network Delay on Different Cluster Head

Figure 8 shows throughput versus time comparison between fixed cluster head, random cluster head selection scheme, adaptive cluster head selection schemeand adaptive cluster head selection scheme with priority for mobile network. As depicted from results, higher throughput is achieved in adaptive cluster head selection scheme with priority.

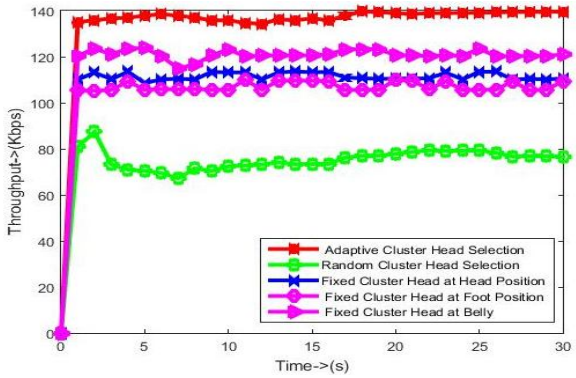

Figure 8. Mobile Network Throughput on Different Cluster Head

Figure 9 shows bandwidth efficiency versus time comparison between fixed cluster head, random cluster head selection scheme, adaptive cluster head selection scheme and adaptive cluster headselection scheme with priorityfor mobile network. As seen from results, higher bandwidth efficiency is achieved in adaptive cluster head selection scheme with priority.

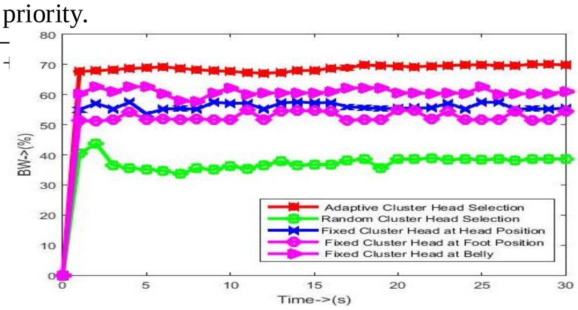

Figure 9. Mobile Network BW efficiency on Different Cluster Head

Figure 10 shows power consumption comparison between fixed cluster head, random cluster head selection scheme, adaptive cluster head selection scheme and adaptive cluster head selection scheme with priorityfor mobile network. As shown from results, low power consumption is achieved in adaptive cluster head selection scheme with priority.

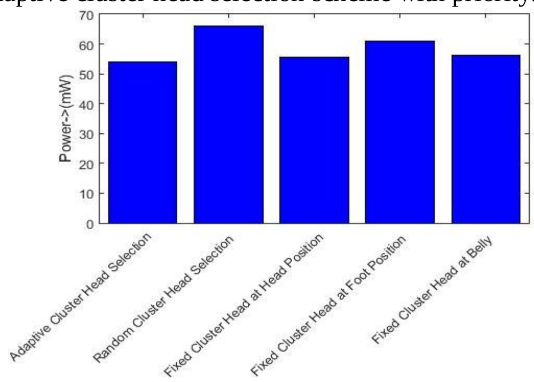

Figure 10. Mobile Network Power Consumption on Different Cluster Head

As the cluster head node has maximum number of connections available in Adaptive cluster head selection scheme, that's why it is easier for other nodes to access cluster head, which results in better performance. Adding priority further enhances its performance.

While in random cluster head selection scheme, destination node may or may not have enough amount of connections to accommodate nodes, which results in more delay, more power consumption and lower throughput.

Fixed cluster head selection schemes show better results as compared to random cluster head selection schemes, because in this case, randomly selected cluster head is not easily accessible as compared to fixed cluster heads for current posture.

Another important thing which is depicted from these results is that adaptive cluster headselection scheme and adaptive cluster head selection scheme with priority show steady behavior after 20 seconds, because at that time, network has adopted a cluster head, which gives ultimate performance. This behavior is lackingin random cluster head selection scheme.

CONCLUSIONS

Inappropriate cluster head selection scheme is one of the major factors of data loss in WBAN. Adaptive cluster head selection scheme with nodal priority is proposed in this paper. This scheme is based upon adaptive cluster head selection using link state table which helps in reducing network delay, mean power consumption and increasing network throughput. In the proposed scheme, cluster head for data packet will be adaptive to the variation in number of connections that each node holds. The numberof connections for every node is present in link state table. The node havingmaximum number of connections will be selected as the cluster head and other nodes will consequently communicate with this node. Nodal priority through power is also introduced to make WBAN more efficient. Our proposed scheme outperforms IEEE 802.15.6 based CSMA/CA in all major aspects i.e. meanpower consumption, network delay, network throughput and network bandwidth efficiency. Thus our proposed scheme has shown significant improvement in IEEE 802.15.6 based CSMA/CA.

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