WDT-CH: Watch Dog Timer Cluster Head Node based Sensor Node - Master Operations in Wireless Mobile Ad-Hoc Networks (WMAN)

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Abstract

Objectives: To increase the security level with improved energy efficiency for emerging application developed under Wireless Mobile Ad-Hoc Networks. Method/Statistical Analysis: In order to get the increased level of security and energy efficiency, a WDT-CH (Watch Dog Timer based Cluster Head) node is deployed to do master operation of the WMANET. This WDT-CH is increasing the network lifetime by handling network’s master operations. The network is constructed by deploying the random nodes in cluster basis. As more number of clusters is created, a stipulated number of nodes can be placed in each cluster in equal manner. WDT-CH is a watch dog timer based CH node which acts as a station keeping node. In each level, there is a main selection and redundant selection of WDT-CH node. At a time, one node is taken to monitor the other nodes in each cluster. By this, all nodes have health status in different clusters by the help of maintaining the status word. Also Master operations are included for obtaining node information through status word. Routing tree is used to discover the path for data communication and encryption technique in the path is used from source to sink via Key Distribution Centre (KDC). All these operations are managed by WDT-CH node and sensor nodes.

Findings: The entire proposed approach is simulated in Network simulator software and it reveals, how effectively energy level is maintained in the network. By implementing the WDT-CH algorithm, routing tree and secured key based encryption methods the overall throughput, Packet Delivery Ratio (PDR), End-to-End delay and energy may be effectively managed.

Application/Improvements: The simulation was compared with the existing approaches and found that the Packet Delivery Ratios increased to 0.18% than the existing research works.

Keywords: Clustering, Energy Efficiency, Mobile Ad-Hoc Network, Watch-Dog-Timer Based Cluster Head

1. Introduction

Wireless Mobile Ad-Hoc Networks (WMANs) provide more supportive services having the best effort in real-time surveillance due to its prevalence. These networks need to provide Quality of Service in terms of bandwidth, less energy consumption and less delay. In1, discussed about distributing the traffic to save the node energy where it avoids node early expiration due to overload. To do this, load balancing is combined with the energy aware routing mechanism called as Path Efficient and Energy Aware Ad Hoc Multipath Distance Vector (PE-EA-AOMDV) routing protocol. In3, a novel video steganography method is applied by integrating Haar Integer Wavelet Transforms (IWT) and Least Significant Bits (LSB) substitution for hiding the data over RGB channels extracted from video file. This process is carried out on text binary form of the data. Power consumption is reduced by applying a novel power management system where it utilizes a pack of two solar powered batteries and automatic battery switching system. This battery system is used to replace the real time battery used in the node1. But this battery replacement system is used only in certain kinds of applications. In4 reported that the link

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can be identified. In the author used a recursive least square algorithm combined with reduced communication for increasing the throughput of the network in all kind of distributed networks. Amplify-and-Forward method was proposed by for data transmission where the data error, energy consumption among the sender and receiver are rectified and reduced respectively. Whereas the existing energy efficient protocols, mechanisms are not satisfied the user in terms of security. This paper proposed a secured clustering approach where energy efficiency with security is provided by integrating security mechanism and clustering approach together. The security is given in terms of examining nodes, timing and other relevant information collected during data transmission. In the existing research, the author discussed and proposed Defending against DoS (DAD) where DAD works in all the ways to detect and prevent DOS attack. Identity verification, Static IP assignment verification and Authkey based communication and packet monitoring with time stamp and IP. But WDT-CH approach improves the efficiency of MANET in terms security and improved QoS.

2. Problem Statement

Given a network G is defined as $N \times N$ is deployed with $M$ number of nodes randomly. At initial level all nodes energy is assigned to the maximum limit. In the network base station is considered as a sink node or receiver. The entire nodes are deployed in the form of clusters, where each cluster is assigned with a Cluster Head. The Cluster Head is also behaved as a timer called “Watch Dog Timer (WDT-CH)-Cluster Head” and it is used to trace the health status of all the nodes deployed in the region specified in specific time called 32 milliseconds. The nodes which are in the path say P will be active throughout the communication. The algorithm runs if ANDed signal of all the nodes in the path should be active. Because of the modes specified node energy is utilized in a very least manner compare to earlier approaches. During sleep mode, no operation is carried out until active or link message to WDT-CH arrives. The message which is transmitted from source to sink is encrypted and decrypted and it is controlled by key distribution management. This key distribution is operated by the WDT-CH nodes in the network. The nearest WDT-CH node for the path initially distributes public key to the nodes in the path. Based on routing table the next hop node is identified and previous node called source node where data packets resides will ask key from WDT-CH node. Now WDT-CH node check for the updated status word from the node and sends key to the source node and one key to next hop node. The same operation follows until message packet or data packet reaches sink node. During this operation if any node fails to transmit the encrypted message packet to the next hop node within the specific time the expected node sends negative acknowledgement to WDT-CH node. In this case, WDT-CH node resend from the previous node by providing different key for message packet. The data packet is collected from the source and encryption done in WDT-CH side and transmitted directly to the next hop node where data transmission resumes. By this security is ensured in an upper level to prevent data leak from the message packet because authorized nodes are participating in the communication and it is monitored by a special monitor node called WDT-CH node.

3. Network Model

A restricted amount of nodes are deployed in the network as cluster wise. Each cluster comprises M number of nodes where M ranges from 1 to 5. Each cluster has minimum of one to maximum of three WDT-CH nodes for improving the security and node status monitoring. Base station is considered as a sink node in which for all paths the sink node is the destination node and it is depicted in Figure 1. Initially all nodes are assigned with Node-ID, initial Energy as 100, location (x, y) and cluster-ID. Each Node-ID is clubbed with cluster-ID belongs to the corresponding cluster where the node is placed. Here maximum number of cluster is restricted to 4. Based on this cluster number nodes are identified. At every sample interval each node in the cluster sends its own status word to the selected WDT-CH node. Actually WDT-CH node is considered Main and Redundant. If anyone WDT-CH node fails in the network, other WDT-CH node will be considered for loop. Hence redundant WDT-CH nodes are kept spare for the cluster in the network. The selected WDT-CH node receives the status word from all the nodes assigned in the cluster and updates the same to base station in case if any node is fault or fails.

Figure 1. Proposed network model.
In the existing clustering approaches the cluster nodes transmit data to CH, the CH transmits the gathered data to BS directly or through other nearest CH to BS. To ensure the data correctness if the status word continuously received from the particular node by stating fail mode for 3 times, then only corresponding node is considered for removal and detach from network. This 3 times check is to ensure the node failure for considerable time. One counter will be run if fail status of node is identified for first time for the corresponding node. If it crossed three then it reset the counter to zero and make that node as a fault node and provide the status to base station stating that not to consider the node for furthermore. The status word is depicted in Figure 2.

The status word transmission is depicted in Figure 3. The nodes which belong to WDT-CH node in that cluster, specifies how node is transmitting the status word to it.

Figure 2. WDT-CH Node interaction with sensor nodes.

Figure 3. Status word header format.

Example, consider the bit pattern 11011100 is received by WDT-CHN as an update from node 12 at time \( t \). From this pattern LSB four bits specifies the node-ID, here 1100 called node-ID is 12. And fourth and fifth bit represents the cluster number, here 01 represents node-12 belongs to cluster-2. And MSB two bits represent the state of node, here 11 represents the node-12 is active and health status is OK. In other case if WDT-CH node receives the bit pattern 00111100 then according to the logic by extracting the MSB two bits, it clearly tells that the node is in non-active mode. In this case WDT-CH will not assign the node as a fault node in very first case. Instead one up counter is triggered from WDT-CH side to keep track the same received from the node-5 in next update. If counter reaches 3, then WDT-CH treat the node-5 as a faulty node. The bit pattern and the corresponding mode are depicted in Table 1.

### Table 1. Bit pattern for mode and cluster selection for status word

| Bit Pattern | Mode                | Cluster |
|-------------|---------------------|---------|
| 00          | Non-Active / Not-OK | Cluster-1 |
| 01          | Idle                | Cluster-2 |
| 10          | Sleep               | Cluster-3 |
| 11          | Active /OK          | Cluster-4 |

Idle and sleep mode in the received pattern is generally don’t care bits because both patterns are set in communication. If number of nodes increases in clusters or number of clusters are increases four then each bit pattern size will vary up to 16 bits.

- **Lemma-1:** Consider the CH set \( \{WDTCH_1, \ldots, WDTCH_j\} \) is a set of link timer for the given network at an interval span of time. It updates the communication link to master sink or base station is depicted in Figure 4.

\[
WDTCH_1 \in \{N_1, N_4, \ldots, N_j\}, \quad WDTCH_j \in \{N_j, N_4, \ldots, N_1\}
\]

- **Theorem-1:** Watch dog timer node updating status to base station at time \( t \).

**Algorithm:**

1. **Watch dog timer node chk.**

**//Specification:** WDT-CH timer is a network node which keeps track the status word of all the assigned nodes in the cluster for health check in Equal intervals.

**//Precondition:** All nodes are assigned with a new energy level and authorized by BS.

**//Exit criteria:** All assigned nodes health check receive 0.

**Algorithm-1: WDT-CH_chk_Node ( )**

Begin:

i. \( G = (Cluster_1, Cluster_2, \ldots, Cluster_j) \) // valid graph \( G \)

ii. **WDT-CHN: Watch Dog Timer Cluster Head Node based Sensor Node - Master Operations in Wireless Mobile Ad-Hoc Networks (WMAN)**

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iv. for all \( j \geq 3 \), the graph node \( G_j \) is also in graph \( G \).

**Theorem-2:**

\[
G = \{G^1, G^2, \ldots, G^i\} \quad \text{(or)} \quad G = \{G^i \mid i = 1, 2 \}
\]

**Solution:**

Assume graph ‘G’ in a network. Numbers of nodes are \( G = \{G^i \mid i = 1, 2 \} \). Number of node is \( n \). Take any path ‘\( \pi \)’ of \( G \), where \( n \) is called \( \pi \). Then the length of the path is \( |\pi| = n \).

If it crossed three then it reset the counter to zero and make that node as a fault node and provide the status to base station stating that not to consider the node for furthermore.

If node \( G_j \) then increment-counter, if counter > 3 node = non-active / dead node.

Otherwise do nothing end if

**Algorithm-2: Path_Routing_Tree**

**//input:** Network \( G \) with \( \pi \) authorized nodes, Clustered node deployment by Sink node.

**//Precondition:** Active status of WDT-CH node in clustered network.

**//exit Criteria:** Path \( P \) found.

**Path_Routing_tree.**

Begin.

**Algorithm Active Begin then**

ii. Extract 4 bits from LSB of SW and obtain node ID.

vii. for all \( j \geq 3 \), the graph node \( G_j \) is also in graph \( G \).

**Theorem-2:**

\[
G = \{G^i \mid i = 1, 2 \}
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**Algorithm Active Begin then**
call Active;
end loop
return (Ti <- Pi)
end Path, Routing, Tree

• Algorithm 3: Data Packet Transmission
// Input: 1. Path P; 2. Constructed routing tree for path P.
// Output: Path P and Tree Ti is set.
// Exit Criteria: If data packet received by sink or Transmission called off.
Data_pkt, Tx, SrcToSink.
Begin
node <- Pi
next_hop Pi+1
Cluster { Cluster1, Cluster2,……., Cluster i } <- WDT-CH
Loop Cluster1,...Cluster j < P then
WDT-CH<- next_hop(Cluster)
(Cluster, P) -< WDT-CH
Data <- encryption_pkt(data)
Node (Cluster i ) P ) <- Data
end if
node state fails
WDT-CH<- n(-1)
next_hop Pi-1
WDT-CH<- SinkNode(Data)
node(n)data <- WDT-CH
end if
clears data pkt from WDT-CH
Path <- 0
WDT-CHi <- 0
RoutingTree<T<- 0
end DataPkt, Tx, SrcToSink.

The above algorithm has three partitions called steps, they are:
• Watch Dog Timer Based Node Check.
• Path Routing Tree.
• Secured Data Transmission.

WDT-CH based node check is a network node which keeps track the status word of all the assigned nodes in each cluster to derive the health check. There is main and redundant WDT-CH nodes are identified in each cluster to monitor the other sensor nodes in the region. The same is described in Algorithm 1. Consider the network with randomly deployed nodes maximum 4 clusters it will be partitioned. Each sub clusters is organized by WDT-CH node.

At specific time intervals all the nodes in the cluster transfer the status word packet to the selected WDT-CH node for loop. From the status word state of the node is derived with health check and the same is passed to the base station. BS keeps trace of node by status word specification. Status table is maintained if any node information in future requires about the nodes the revised status word details in this status table. This ensures the recent health check of the nodes participated in the network. If health check is affirmative then the nodes are in good condition to support data communication, whereas if health check is not affirmative then from WDT-CH side one counter is assigned to ensure the same health check for 3 time, after 3 count the same status remains from the node, then the node which health is not affirmative is removed from the network. The same is intimated to BS. For future communication or path discovery the node will not be considered.

In path routing tree, the path nodes are connected without ambiguity to the destined node. A path which is considered for communication is done after the collective AND check of all the nodes in the path. Active flag is used in software side reads the active status from the sensor nodes in the path. If this flag is set then based on the routing table, routing is updated with next hop nodes. The same step is followed until all the nodes in the path are considered for routing table update. Finally routing tree is formed based on the valid path and ready for transmission.

Data transmission is starts from the source node by holding the data packet and passed to the authorized node in the path by routing table next hop. Here key distribution scheme is handled by WDT-CH node. Initially WDT-CH node will send key to path nodes for ensuring the communication. Based on the next hop the current node knows the next node and request WDT-CH to pass the data packet to next node. WDT-CH is now assigns two keys one to current node and one to target node. With that encryption happens in current node, the key which sent to target node is used for accepting the data packet. It will not decrypt to identify data; here for acceptance of data packet key is used, the general data is encrypted in initial node. Individual encryption and decryption is to check whether valid nodes in the path are used for communication. With the help of WDT-CH node key is received by both the ends of data transmission tag. If decryption fails or any failures like data packet loss during transmission, WDT-CH node declares transmission failure. This WDT-CH node knows the tag nodes will not use the key in the stipulated time. If no key requirement triggered from tag end, it declares the failure.

In this case, WDT-CH node receives the data packet from the source node and delivers to next hop node where data transmission paused. Then continuity of process is same like proposed method until sink receives the data. After successful completion of data transmission path is cleared and tree is available for next dynamic update.

3.1 Routing Tree

An unambiguous tree structure is formed by linking path nodes from source to sink node which is called BS. Parent child links is established for packets forward. High efficient bandwidth and energy is utilized for data communication.

A node receives the data packet based on the next hop link and in the order of tree structure, a set of protocols and rules are certain to the MAC cluster of node, with the help of WDT-CH node it passes to the other node in an efficient way by secured encryption methods. The tree structure is depicted in Figure 5. The path metrics in the tree obtained is calculated by as follows:

Path Metric in routing tree:

\[ M_p = \frac{\text{No of Hops For Path}}{\text{Max (load in path)}} \]

\[ \text{Probability (Path Success)} = \frac{M_p}{\text{Path Success}} \]

The structure consists of flow control mechanism which acknowledges for every node communication. The proposed approach is comparatively studied with earlier approaches like secured energy efficient mechanism. Parametric like throughput is considered, where successful delivery of message is achieved for every communication. The efficacy of the routing tree mechanism is high due to clustering based tree conversion.

Figure 5. Routing tree structure with sink node including clustering.

4. Simulation Settings

The proposed schemes have been experimented in the simulation environment in ns2. The simulation parameters are shown in Table 2.

The network deployed with 60 nodes, where 15 nodes per cluster and maximum of four clusters in the network can accommodate this 60 nodes with WDT-CH nodes. During the communication the proposed approach functionality is verified and investigates how this approach is efficient in terms of saving the energy and detecting malicious nodes in the network. The simulation results are shown in the following figures and discussed in following section.

| Table 2. Simulation parameters |
|-------------------------------|
| Parameter | Level |
| Area | 1500m x 1500m |
| Speed | 1 to 25 m/s |
| Radio Propagation Model | Two-ray ground reflection |
| Radio Range | 250 m to 300 m |
| Number of Nodes | 15 per cluster and 4 clusters |
| MAC | 802.11x |
| Application | CBR, 100 to 500 |
| Packet size | 50 and above |
| Simulation Time | 50s to 100 s |
| Placement | Random Deployment |
| Malicious Population | Up to 5% |
| Common malicious node | 5% |
| Pause Time | 5ms |

5. Results and Discussion

The simulation network taken considerable nodes to pass the algorithm, based on the output the basic metrics like throughput, Packet Delivery Ratio (PDR), End End Delay. Residual energy is calculated and the same is compared with earlier approach. Time with delay is compared and shown in Figure 6. Time is considered in seconds and delay is verified with the data transmit of packets from source and receiver of destination. Each level of iteration the node communication is estimated with transmission time and node delay. In existing approach delay obtained is maximum level where time increases. Using WDT-CH nodes here the delay is qualified in transmission stage from one node to the other. If node fails to trigger for data transmission within the specified time, WDT-CH will take care of further process, hence delay is handled optimistic.
Figure 7 depicts the comparison of Packet Delivery Ratio between existing and proposed approach. Number of nodes considered here in terms of 10 to 70, each time the probability of successive PDR obtained is calculated as follows:

\[
PDR = \frac{\# \text{ PacketsReceived}}{\# \text{ PacketsTransmitted}}
\]

For the approximate time within the specified range, how many packets are received by the sink node is given in the Figure 7. It clearly states that for proposed approach PDR is high that is for maximum number of packets transmitted, all packets which is controlled by WDT-CH node is received by the sink node.

In this proposed approach, main goal is how to use energy efficiently when sensor node really not in use. For this several nodes is identified in proposed system, each node usage and activities is clearly handles the anomalies in energy efficiency. It is depicted in Figure 8, number of nodes is compared with energy levels. Node is considered in all cluster levels as per the network model. All nodes are in different modes, mostly in sleep mode except path nodes in action or node busy in sending status word. This approach is compared with existing system; the proposed model defines efficient energy usage between the nodes.

Since this proposed approach follows clustering technique, the efficacy of the energy saving is verified in the simulation. To do this, the simulation is carried out five rounds where in each round the number of nodes deployed is varied. In all the five rounds there are 200 number of nodes in increased from round one to round five. After each round the remaining energy of the cluster nodes are calculated and verified. According to the data size, distance among the nodes and the Cluster Head, Cluster Head to BS energy consumption is changed. When the amount of energy (battery level) goes below a threshold value then the node is considered as dead node. And the dead node can be activated after providing full battery charge or replacing the battery. In this paper the number of dead node ratio proportionally increased by 2.5% than the previous level. Hence this proposed approach is efficient in terms of monitoring, acknowledging, energy efficiency and throughput and shown in the Figure 6 to Figure 9.

6. Conclusion

The main objective of the paper is to reduce the energy consumption among the nodes and improving the security. To do this WDT-CH node based monitoring the nodes health status to communicate efficiently. Here, WDT-CH node is acting as a Cluster Head as well as monitoring node in the clusters and since it is efficient to provide security and energy efficient in the network. This secured clustering leads to prevent data loss and reduce the delay while routing. From the simulation results it is clear and concluded that the proposed WDT-CH approach is efficient mechanism for improving secured energy efficient network.

In future, if the status word size increases, network size also increase with more number of nodes. Over to this, WDT-CH node for each cluster main and redundant is used here, if any one WDT-CH sensor node fails, the other one is considered for a loop. If number of nodes increases, clusters in the network also increases. Hence, WDT-CH shall be selected based on critical access to the cluster nodes. By this proposed model, energy level is consumed up to the maximum consumption using different mode specified and security is implemented throughout the communication.

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