XLP: An Integrated Protocol for Efficient and Reliable Communication in Wireless Sensor Networks

Akbar Saleem. Mohammad, Jitendranath Mungara

Abstract: ***Now-a-days, vast majority of the existing solutions are based on the classical layered protocol approach, which leads to significant overhead. Severe energy constraints of battery-powered sensor nodes necessitate energy-efficient communication in Wireless Sensor Networks (WSNs).In this paper, a cross-layer protocol (XLP) is introduced, to achieve congestion control, routing between nodes, and medium access control in a cross-layer fashion. XLP is the first protocol that integrates functionalities of all layers from PHY to Transport into a cross-layer protocol. The design principle of XLP protocol is based on the initiative determination concept, which enables receiver-based contention, initiative-based forwarding, congestion control, and duty cycle operation to realize efficient and reliable communication in WSNs. This concept constitutes the core part of the XLP,A cross-layer analytical framework is developed to investigate the performance of the XLP. XLP improves the communication performance and outperforms the traditional layered protocol architectures in terms of both network performance and implementation complexity***

Index Terms: ***XLP protocol, congestion control, routing between nodes, medium access control, WSN's.***

I. INTRODUCTION

The design principle of XLP is a unique cross layering such that both the information and the functionalities of three fundamental communication paradigm (medium access, routing between nodes, and controlling congestion) are considered in a single protocol operation.. The design principle of XLP is based on the concept of initiative determination, which enables receiver-based contention, initiative forwarding, controlling congestion, and duty cycle operation to realize efficient and reliable communication in WSNs. The initiative determination concept coupled with the receiver-based contention mechanism provides freedom to each node participating in communication. In WSNs, the major perspective of a communication suite is to successfully transport event information by constructing (possibly) multi-hop paths to the destination. To this end, the cross-layer initiative determination concept constitutes the core of the XLP and implicitly incorporates the intrinsic communication functionalities required for successful communication in WSNs.

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II. XLP: CROSS-LAYER PROTOCOL FOR WSNS

Before explaining the XLP operation, we first introduce the initiative determination concept, which constitutes the main part of the XLP.

2.1 Initiative Determination:

The initiative determination concept in combination with the receiver-based contention mechanism to determine node willingness to participate in communication or not.. Consider a node, i, which starts transmission by informing its neighbors nodes that it has a packet to send. This is achieved by sending a request to send (RTS) packet. After receiving this packet, each neighbor of node i decides to participate in the communication or not. This decision is made through the concept of initiative determination based on the current state in which node will be. The initiative determination is a binary operation where a node start deciding to participate in communication if its initiative is set to 1. Denoting the initiative as I, it is determined as follows:

$$I = \begin{cases} 1, & \text{if } \begin{cases} \xi_{RTS} \ge \xi_{Th} \\ \lambda_{relay} \le \lambda_{relay}^{Th} \\ \beta \le \beta^{max} \\ E_{rem} \ge E_{rem}^{min} \end{cases} \\ 0, & \text{otherwise.} \end{cases}$$

Fig 1: Initiative Determination

The initiative is set to 1 if all four conditions are satisfied, and the node is ready to participate in communication where each condition constitutes a certain communication functionality in XLP. The first condition, states that reliable links to be constructed for communication based on the current channel conditions. For this purpose, it is required that the received signal-to- noise ratio (SNR) of an RTS packet, RTS, should be greater than threshold value 'Th' for a node to participate in communication. The effect of this threshold value on routing and energy consumption performance will be analyzed and the most perfect and good value of this threshold will be chosen. The second condition relay, and the third condition maximum, conditions are used for local congestion control in XLP.

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The second condition prevents congestion by limiting the traffic a node can participate. More specifically, a node participates in the communication if its relay input rate, relay, is lower than some threshold 'Th' relay .The third condition states that the buffer occupancy level of a node does not exceed a specific threshold, max, so that the node does not effect to buffer overflow and the congestion is prevented. The last condition ensures that the remaining energy of a node Erem stays above a minimum value, Emin remaining .

This constraint helps preserve uniform distribution of energy consumption throughout the network.

III. SYSTEM ARCHITECTURE OF XLP PROTOCOL

From the below Fig.2 Shows the Architecture of the XLP protocol.The figure Fig 2.1(a) shows the two new interfaces are created at layer 3 for information flow from layer 4 to layer 3 and layer 2 to layer 3. Fig 2.1 (b) is another example of cross layer design Where firstly layer 2 and layer 1 are combined to result in super layer and secondly the design of layer 3 is dependent on the design of layer 4 which means that any change in layer 4 will show effect in layer 3 as well. Fig 2.1(c) shows the break of reference architecture by introducing another vertical layer, which is used for vertical calibration fine tuning and performance of parameters of one layer is used by the feedback provided by another layer.

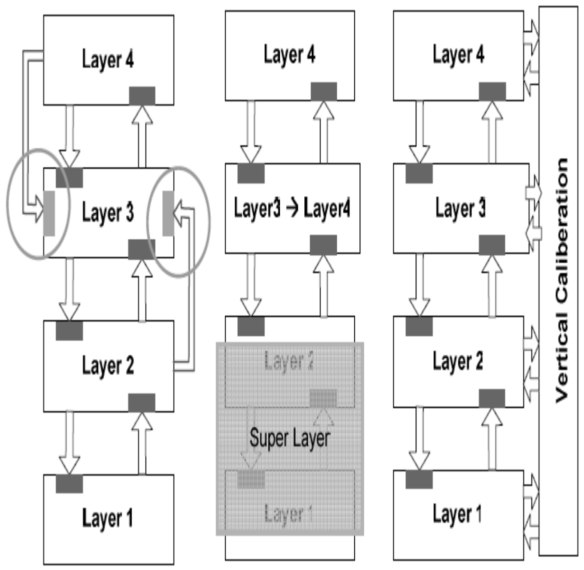


Fig 2.1 (a) Fig 2.1(b) Fig 2.1(c)

Fig 2 System Architecture of Cross-layer Protocol.

IV. SOFTWARE DESIGN MODULES

4.1 Source Node

Here the source node uses the Gpi(Geographical priority Index) value and Qpi(Queue priority index) value. If these values matches with the value of destination node. Then we can transmit data the nodes successfully.

4.2 Destination Node

Based on the priority index values successfully it restores the data from the source node.

4.3 Coloring Schema

Each node is assigned itself a different color, which is used to participate in communication from source node to destination for unique identity.we use ALBA-R concept for coloring nodes.

V. ALGORITHM DESCRIPTION

The most commonly used algorithm is **:**

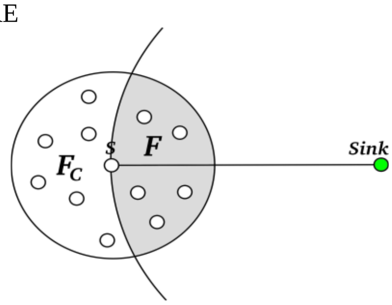
ALBA: An Adaptive Load-Balanced Algorithm for Geographic Forwarding in Wireless Sensor Networks. This Algorithm resolves the following issues.

- It defines a node awake/asleep schedule.
- Reduces the maximum number of hops required to reach the destination.
- ALBA-R algorithm improves scalability & decreases congestion.
- Distributes traffic uniformly in the network, favoring low congested nodes and avoiding overloaded regions.
- Controls channel access efficiency through an adaptive transmission of "batches of packets".
- Re–send the packets along another route when connectivity holes occur
- ALBA-R assigns to relay nodes based on Queue-based Priority Index and a Geographic Priority Index (QPI and GPI)
- The QPI measures the correctness of a node for forwarding a packet

QPI = d(Q + NB)/Me – 1

1. Packets are sent in bursts
2. Q = Queue occupancy
3. NB = Number of expected packets (in a burst)
4. M =Average length of a burst that can be sent by the relay node

- The GPI value is based only on geographical coordinates: The closer a node to the sink, the higher will be the GPI
- The relay is selected based on QPI value in case of multiple relays with the same QPI value, the GPI value breaks the tie.
- Each Node is assigned with colors and try to reach the "yellow brick route"
- Initially all the nodes are yellow →they look forward for relays in F.
- No relays in F →the node changes to red and it looks for (yellow, red) relays in FC
- No relays in FC → the node changes to blue and it looks for (red, blue) relays in F. This can be shown in below FIGURE



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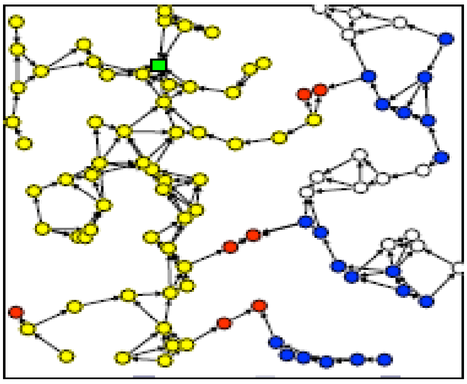

FIG: 3 Alba-R Algorithm

VI. XLP: CROSS LAYER PROTOCOL MECHANISM'S

6.1 Prioritization Mechanism

Based on this network model, the protocol operation details are explained in the following sections according to Fig.

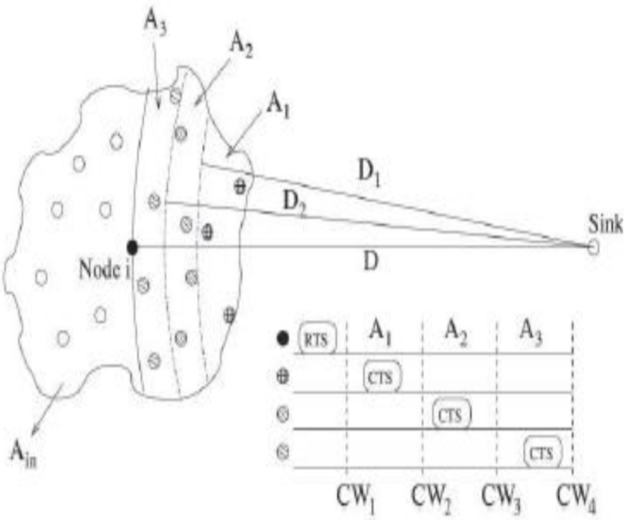

Fig 4: Prioritization Mechanism

6.1.1 Transmission Initiation

When a node i has a packet to transmit, it first listens to the channel for a specific period. If the channel is already occupied, the node performs back off based on its contention window size, CWRTS. When the channel is idle, the node transmits an RTS packet, which contains the area information of itself and the destination. This packet also show the link quality and helps the neighbors to execute receiver contention. When a neighbor node i receives an RTS packet, it first checks for the source and sink locations. We refer to the region where the neighbors nodes that are closer to the sink reside inside as the feasible region and the remaining neighborhood as the infeasible region. A node which receives a packet first checks whether it is inside the feasible region or not. To save the energy, nodes inside the infeasible region jump to sleep for the duration of the communication. The nodes which reside inside the feasible region perform initiative determination as explained .A node if willing to participate in communication, it performs receiver contention as explained next.

6.1.2 Receiver Contention

The receiver contention of XLP leverages the initiative determination concept with the receiver-based routing mechanism. After an RTS packet is received, if a node has an initiative to participate in the communication, it carry out receiver contention to forward the packet. The receiver contention is determined on routing level of each node, which is calculated based on the performance a packet would make if the node starts forwards the packet. The feasible region is divided into Np priority regions, Nodes which survive for longer progress have higher priority than other nodes. According to the location information, each node determines its priority region and performs contention for medium access as explained next.

Each priority region, Ai, corresponds to a back off window size, CWi. Based on the location, a node backs off for cwi, where cwi is randomly chosen such that ;CW max where This back off scheme helps in differentiating the nodes of different progress into different prioritization groups. Only nodes that reside inside the same group contend with each other. The winner of the competition sends a CTS packet to node i indicating that it will forward the packet. On the other hand, if during backoff, a potential receiver k receives a CTS packet, it determines that another potential receiver j with a longer progress has accepted to forward the packet and node 'k' jumps to sleep for the duration of the communication. The case for Np priority regions. Based on their potential results, each feasible node represent to one of the three priority regions A1, A2, or A3. The back-off scheme , where the possible time when a CTS packet can be sent are calculated. As an example, if a node present in A2 satisfies the initiative function, it first waits for CW2 in addition to a random cw2 value. Consequently, the node in A2 can transmit a CTS packet only if no other node in A1 transmits a CTS packet. When the node i receives a CTS packet from a potential receiver, it shows that the receiver contention has ended and sends a DATA packet with the position of the winning node in the header. The CTS and DATA packets both inform the other contending nodes about the transmitter-receiver pair. Hence, other nodes stop competing and switch to sleep mode. In the case of two nodes sending CTS packets without knowing each other, the DATA packet sent by node i can resolve the contention. It may happens that multiple CTS packets from the same priority region can compete with each other and a node from the lower priority region can be selected. XLP protocol does not try to resolve this problem as this probability is very low since the contention region is already divided into multiple regions and the cost of trying to resolve this outweighs the gains. Simply Note that node i may not receive a CTS packet because of three reasons: 1) CTS packets may collide, 2) there exists no potential neighbors nodes with I = 1, or 3) There exist no nodes in the feasible region. However, node i cannot differentiate these three cases by the lack of a CTS packet. Hence, the neighbors of node i send a keep alive packets after Np CWj cw if no communication is overflow. In this case, cw is a random number, where CW max and Np is the number of priority regions as explained before.

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The existence of a keep alive packet identifies the sender that there exist nodes closer to the sink, but the initiative is not met for any of these nodes. With the reception of this packet, the node performs re-transmission. However, if a keep alive packet is not received, the node continues re-transmission of nodes in case there is a CTS packet collision. If no response is received after k retries, node I determines that a local minimum is reached and switches to an angle-based routing mode as explained next.

6.2 Angle-Based Routing

The routing decisions depend on the locations of the receivers nodes, there may be a situation where the packets reach a local minima. In other words, a node may not be able to find any feasible nodes that are closer to the destination than itself. This situation is known as a communications void in geographical routing-based method and is generally solved through the technique face routing. Although localized, face routing technique tells a node to communicate with its neighbors to establish a planarized graph and construct routes to traverse around the void region. This requires information to be exchange between the neighbors of a node .Due to this there will be communication increases the protocol overhead, so we introduce a solution to face routing,i.e., angle-based routing technique.

The main principle of angle-based routing can be seen in

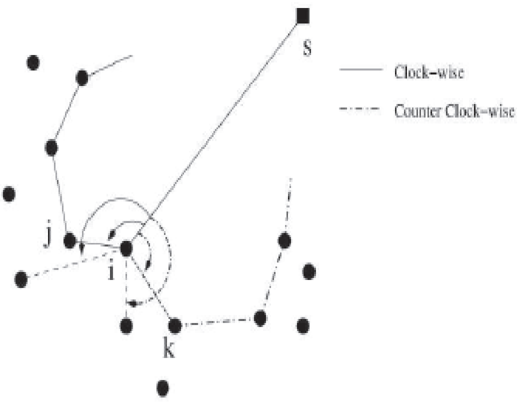

Fig 5: Angle-Based Routing

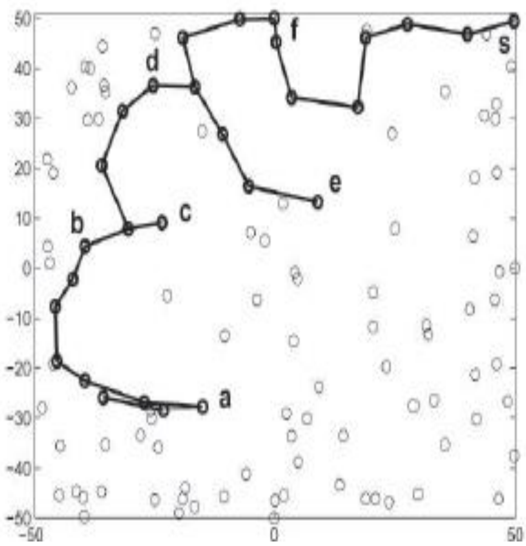

Fig 6: Free Loop Angle based routing

When a packet reaches node i, which is a local minimum toward the sink, the packet has to be routed around the void either in clockwise direction (through node j) or in counterclockwise direction (through node k). Assume that lines are drawn between node i and sink s, as well as between node i and its neighbors. If we compare the angles between line i, s, and the other lines, angle ffsij (angle ffsik) has the smallest angle in the counterclockwise (clockwise) routing direction. Using this property, routes can be constructed around the void. Once the direction is set whether (clockwise or counterclockwise), the packet moves around the void using the same direction. Hence, for angle-based routing, we present the term traversal direction to indicate the direction. Note that the clockwise (counterclockwise) traversal direction refers to the direction of the packets rather than the way the angles are measured. When a node switch to angle-based routing mode, it also sets the traversal direction to clockwise direction and sends an RTS packet, which identifies both the routing mode and the traversal direction. The nodes that receive this packet determine the angle relative to the source-sink direction. Denoting the angle by ij, node j sets its contention window to cij þ cwi, where cwi is a random number and c is a constant. The node with the smallest angle (hence, the smallest contention window) sends a CTS packet and the data communication takes place. This procedure is repeated until the packet reaches a local minimum region. In this case, the traversal direction is set to counterclockwise and the procedure is repeated again. Angle-based routing stops executing and the basic XLP is performed when the packet reaches a node that is closer to the sink than the node that initiated the angle-based routing. A sample route found by this algorithm is shown , where the sink is denoted by s. Since node a is a local minimum, XLP switches to angle-based routing mode in clockwise direction. The packet is routed toward node c, where the traversal direction is changed and the packet reaches node d. Since node d is closer to the sink than node a, the angle-based routing mode is terminated and the packet is forwarded until node e using basic XLP. At node e, a local minimum is reached and the angle-based routing mode is used again. Finally, at node f, this mode is terminated since node f is closer to the sink than node e. The packet is routed from node f to sink s using basic XLP. The correctness of the angle-based routing protocol can be proved by proving that no loops are generated.

VII. PERFORMANCE EVALUATION

XLP Parameters:

The parameters that affect the XLP operation are angle based routing, SNR Threshold, 'Th', and duty cycle, we present the effects of these parameters on the XLP performance in this section.

7.1 The effect of angle-based routing:

It is shown in below Fig, where the route failure rate versus duty cycle parameter is shown for XLP with and without angle-based routing. The results show that route failure rate increases as the duty cycle parameter is decreased. On the other hand, angle-based routing limits the route failure rate to less than 10 percent for T> 0:3. This leads to up to a 70 percent decrease in the failure rate.

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Note that the failure rate of XLP with angle-based routing also increases as ‘T’ is further decreased since the probability that at any given time the network is partitioned increases.

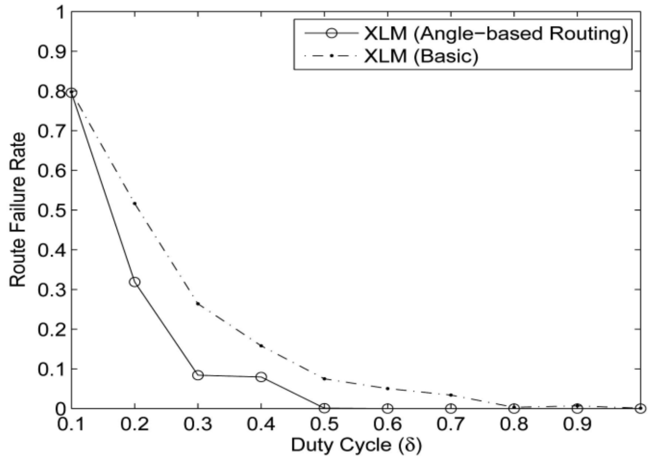

Fig7. Route failure rate for XLP with and without angle-based routing

7.2 Effect of Latency:

In the below FIG end-to-end latency is shown, which reveals that increasing SNR threshold, ‘Th’, improves the end-to-end latency performance up to a certain _Th value. _Th = 10dB results in the lowest latency. It is also interesting to note that there is a suitable operating point for duty cycle _considering end-to-end latency (T= 0:6). Above this value, end-to-end delay starts to increase because of the increase in receiver based contention. Since, for all above performance metrics, ‘Th’= 10dB results in the most efficient performance

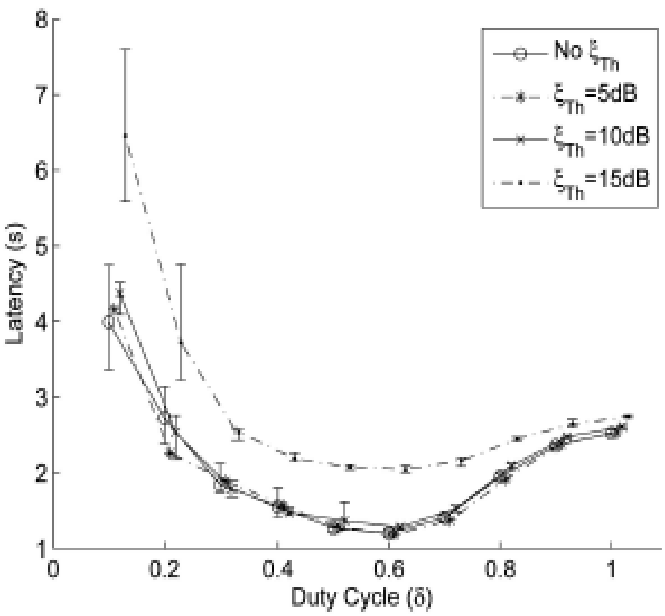

Fig. 8.Average latency versus duty cycle for different values of TH

VIII. RESULTS

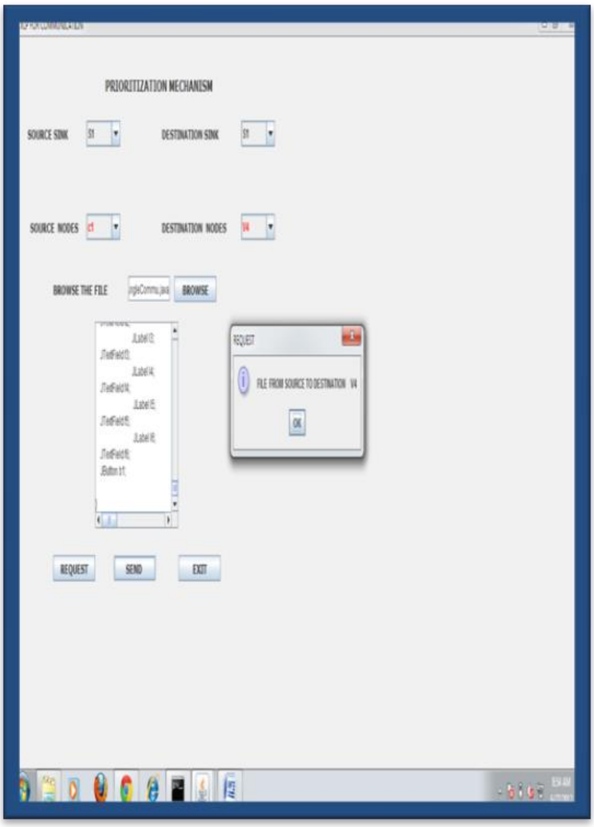

Fig 9: Snapshot of Prioritization Mechanism

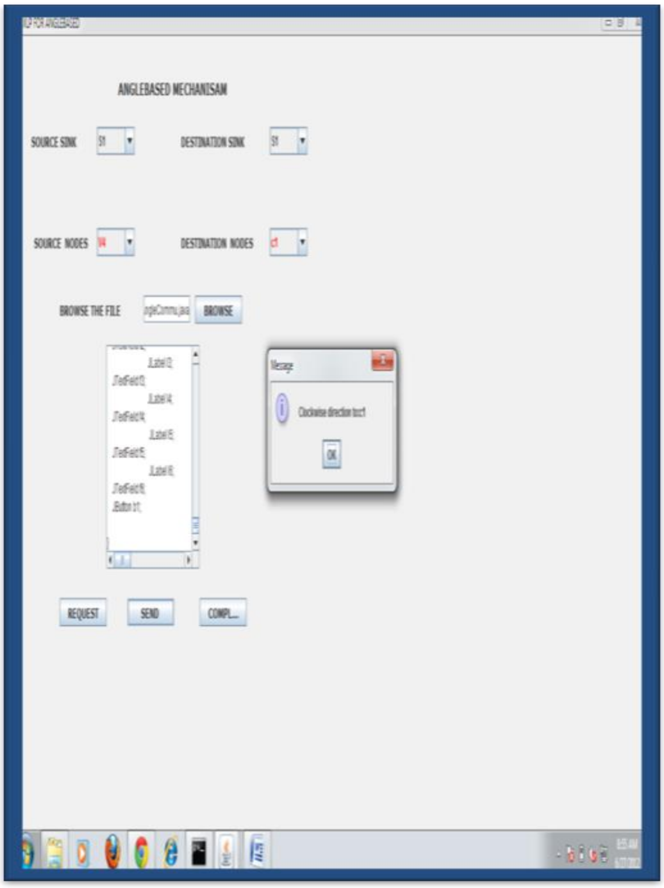

Fig 10: Snapshot of Angle Based routing Mechanism

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IX. CONCLUSION

Recently, cross layering design a communication stack such that the state information flows throughout the stack has been investigated. Recent work on WSNs also reveals that cross-layer integration techniques mostly result in significant energy gains. In this paper, we proposed concept called initiative determination that allows many communication and networking functionalities be defined and implemented in a single protocol. Accordingly, the cross-layer procotcol (XLP) is proposed to provide the functionalities of medium access control, routing between nodes, and congestion control. Based on the initiative determination concept, XLP as a identical proof of concept and performs receiver-based contention, initiative-based for- warding, local congestion control, and distributed duty cycle operation to realize efficient and reliable communication in WSNs. Analytical performance evaluation and simulation results show that XLP significantly improves the communication performance and outperforms the traditional layered protocol architectures in terms of both network performance and implementation complexity.

The ultimate achievement in this cross-layer design technique is to develop a single communication module that is responsible for the functionalities of each networking layer. The concept developed in this work is the first step in this approach which replaces the entire traditional layered protocol architecture that has been used so far in WSNs so that both the information and the functionalities of traditional communication layers are moulded in a single module. Consequently, the future work for our research includes the investigation of various networking functionalities such as adaptive modulation, error control, and topology control in a cross-layer fashion to develop a unified cross-layer communication module.

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