MAC Controlled Clustering Algorithm in Wireless Sensor Network

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Abstract— This project is to avoid the collision while data transferring from one node to another node. Wireless sensor network (WSN) requires robust and energy efficient communication protocols to minimize the energy consumption as much as possible. However, the lifetime of sensor network reduces due to the adverse impacts caused by radio irregularity and fading in multi-hop WSN. A cluster-based scheme is proposed as a solution for this problem. The proposed scheme extends High Energy First (HEF) clustering algorithm and enables multi-hop transmissions among the clusters by incorporating the selection of cooperative sending and receiving nodes. The proposed cooperative MIMO scheme prolongs the network lifetime with 75% of nodes remaining alive when compared to LEACH protocol. In mobile ad hoc networks, nodes are usually powered by batteries with limited energy. To prolong the network life, the energy consumption of the routing task is crucial. In this paper, we proposed a novel topology control scheme for mobile nodes. Adhoc on demand distance vector routing protocol is specially designed for mobile adhoc networks with reduced overhead using Expanding Ring Search technique. But energy consumption should also be considered in MANET due to battery constrain of the nodes.

Key words: WSN, HEF, MIMO, LEACH, ADHOC, MANET

I. INTRODUCTION

A wireless sensor network (WSN) consists of sensor nodes capable of collecting information from the environment and communicating with each other via wireless transceivers. The collected data will be delivered to one or more sinks, generally via multi-hop communication. The sensor nodes are typically expected to operate with batteries and are often deployed to not-easily-accessible or hostile environment, sometimes in large quantities. It can be difficult or impossible to replace the batteries of the sensor nodes. On the other hand, the sink is typically rich in energy. Since the sensor energy is the most precious resource in the WSN, efficient utilization of the energy to prolong the network lifetime has been the focus of much of the research on the WSN.

The communications in the WSN has the many-to-one property in that data from a large number of sensor nodes tend to be concentrated into a few sinks. Since multi-hop routing is generally needed for distant sensor nodes from the sinks to save energy, the nodes near a sink can be burdened with relaying a large amount of traffic from other nodes.

Sensor nodes are resource constrained in term of energy, processor and memory and low range communication and bandwidth. Limited battery power is used to operate the sensor nodes and is very difficult to replace or recharge it, when the nodes die. This will affect the network performance. Sensor nodes are deployed to gather information and desired that all the nodes works continuously and transmit information as long as possible.

This address the lifetime problem in wireless sensor networks. Sensor nodes spend their energy during transmitting the data, receiving and relaying packets. Hence, designing routing algorithms that maximize the life time until the first battery expires is an important consideration. In most of the applications of wireless sensor networks are envisioned to handled critical scenarios where data retrieval time is critical, i.e., delivering information of each individual node as fast as possible to the base station become an important issue. It is important to guarantee that information can be successfully received to the base station the first time instead of being retransmitted.

In wireless sensor network data gathering and routing are challenging tasks due to their dynamic and unique properties. Many routing protocols are developed, but among those protocols cluster based routing protocols are energy efficient, scalable and prolong the network lifetime .In the event detection environment nodes are idle most of the time and active at the time when the event occur. Sensor nodes periodically send the gather information to the base station. Routing is an important issue in data gathering sensor network, while on the other hand sleep-wake synchronization are the key issues for event detection sensor networks.

II. PROPOSED SYSTEMS

Cluster heads are selected according to the probability of optimal cluster heads determined by the networks. After the selection of cluster heads, the clusters are constructed and the cluster heads communicate data with base station. Because LEACH is only depend on probability model, some cluster heads may be very close to each other and can be located in the edge of the WSN. These disorganized cluster heads could not maximize energy efficiency. To overcome the defects of LEACH methodology, a cluster head election method HEF algorithm has been introduced. This method proved that the network lifetime can be efficiently prolonged by using fuzzy variables (concentration, energy and density). Providing a trustworthy system behavior with a guaranteed hard network lifetime is a challenging task to safety-critical and highly-reliable WSN applications. For mission critical WSN applications, it is important to be aware of whether all sensors can meet their mandatory network lifetime requirements. the High Energy First (HEF) algorithm is proven to be an optimal cluster head selection algorithm that maximizes a hard N-of-N lifetime for HC-WSNs under the ICOH condition. Then, we provide theoretical bounds on the feasibility test for the hard network lifetime for the HEF algorithm. Our experiment results show that the HEF algorithm achieves significant performance improvement over LEACH, and HEF's lifetime can be bounded.

III. ARCHITECTURAL BLOCK DIAGRAM

1) Step 1. After starting the network, the wireless sensor nodes will be divided into several clusters in the WSN.
2) Step 2. One node will be chosen as the cluster head in each cluster area. This cluster head will use a negotiation system to send joining messages to the nodes near the cluster head.
3) Step 3. After that, the cluster-heads will send invitations to the wireless sensor nodes in each cluster asking them to join the cluster-heads to form the clusters. The second phase includes the \transferring data process" and the \distributing the role of cluster head process" including the following three steps. The AODV routing protocol is responsible for sending the data from the source to the destination nodes. The role of distribution is determined by regularly selecting a set of new cluster-heads based on the weight value.

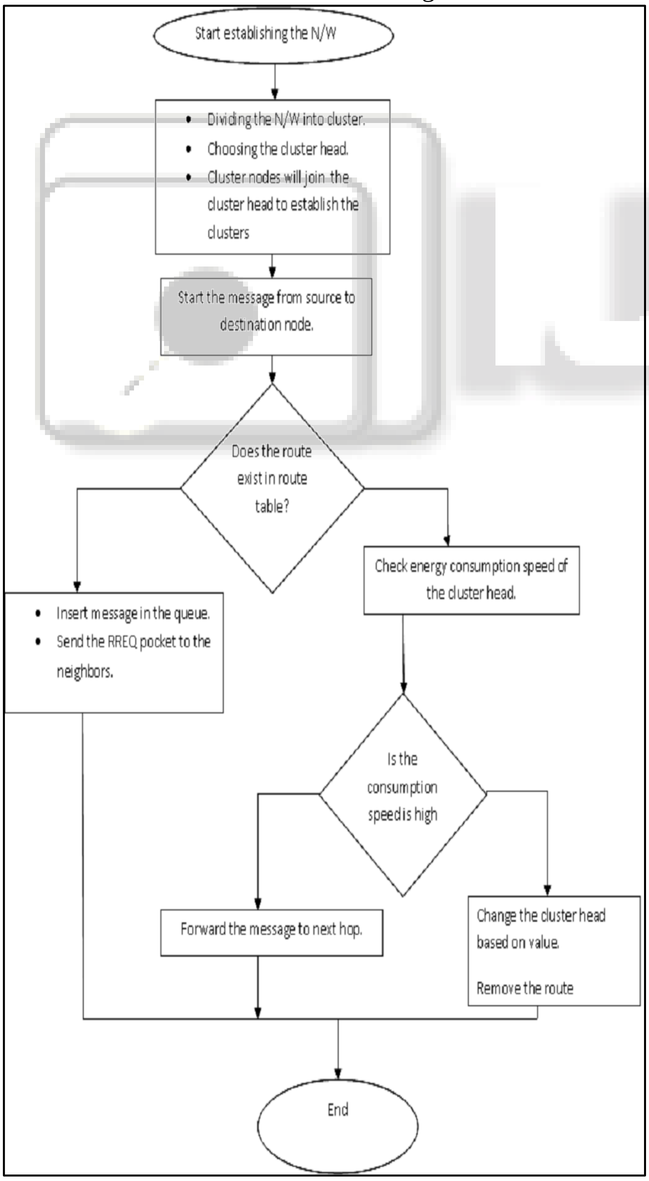

Fig. 1: Architectural Block Diagram

4) Step 4.When any wireless sensor node needs to send a message, it has to check its routing table and look for a path to the destination node. Therefore, if the route is available in the routing table, it will forward the message to the next node. Otherwise, the message will be saved in a queue, and the source node will send the RREQ packet to its neighbours to commence the discovery process.
5) Step 5. During the forwarding of the message to the destination, the rate at which power is consumed by the cluster head will be calculated based on the energy model. If the energy consumption speed is high, then the procedure will choose another node to act as the cluster head based on the value.
6) Step 6. Then, the procedure will remove the route from the routing table of the source, which will lead the source node to initiate the discovery process in phase 2 again and a new path to the destination node through the new cluster head.

IV. MODULES

A. Cluster Head Selection:

The cluster heads may be special nodes with higher energy or normal node depending on the algorithm and application. Here base station is a cluster head performs computational functions such as data aggregation and data compression in order to reduce the number of transmission to the base station (or sink) there by saving energy. One of the basic advantages of clustering is that the latency is minimized compared to flat base routing and also in flat based routing nodes that are far from the base station lacks the power to reach it. Clustering based algorithms are believed to be the most efficient routing algorithm for the WSNs. The basic principle of its efficiency is that it operates on the rule of divide and conquers. Clustering along with reduction in energy consumption improves bandwidth utilization by reducing collision. Work is currently underway on the energy efficiency in WSNs which will result from the selection of cluster heads.

B. Energy Consumption:

Transmission in WSNs is more energy consuming compared to sensing, therefore the cluster heads which performs the function of transmitting the data to the base station consume more energy compared to the rest of the nodes. Clustering schemes should ensure that energy dissipation across the network should be balanced and the cluster head should be rotated in order to balance the network energy consumption. The communication model that wireless sensor network uses is either single hop or multi hop. Since energy consumption in wireless systems is directly proportional to the square of the distance, single hop communication is expensive in terms of energy consumption.

C. Energy Efficient Routing:

In contrast to simply establishing correct and efficient routes between pair of nodes, one important goal of a routing protocol is to keep the network functioning as long as possible. As discussed in the Introduction, this goal can be accomplished by minimizing mobile nodes' energy not only during active communication but also when they are inactive. Transmission power control and load distribution are two approaches to minimize the active communication energy, and sleep/power-down mode is used to minimize energy during inactivity.

- energy consumed/packet,
- time to network partition,
- variance in node power levels,
- cost/packet, and
- Maximum node cost.

V. PROPOSED CLUSTER BASED WSN ARCHITECTURE

We have introduced a resource reachable node called server node (SN). It has the ability to cover long transmission range. Server node (SN) is deployed in a location where all the nodes of each cluster are easily reachable. If it is not reachable, it is recommended to add another server node (SN). Due to extra processing capability sever node (SN) are responsible for selecting cluster head from candidate nodes. The purpose of introducing SN is to closely monitor the operation of sensor nodes in a cluster and command them for specific operations.

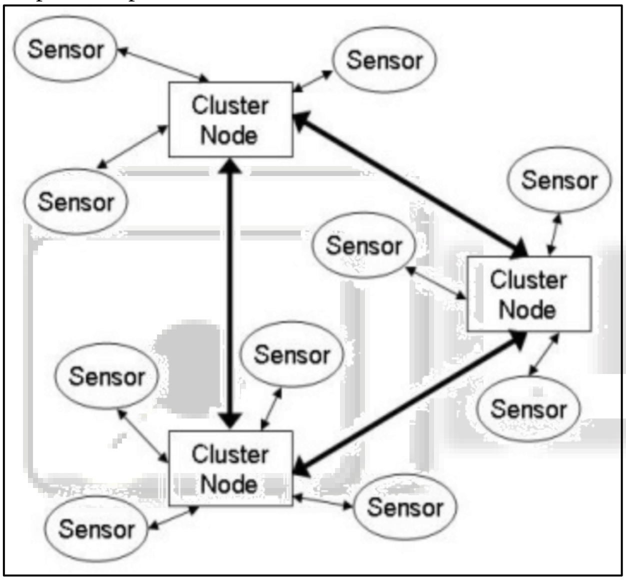

Fig. 2: Proposed Cluster Based WSN Architecture

VI. SELECTION OF CANDIDATE CLUSTER HEAD

The selection of cluster head becomes highly challenging when there is an uneven distribution of sensor nodes in clusters. In order to make the cluster head (CH) selection algorithm more accurate, we first identify the candidate sensor nodes for cluster head and then select the best among them. In order to select candidate cluster heads from each cluster, we use the K-theorem. The philosophy behind the K-theorem is to select a candidate CHs based on the bunch of sensor nodes.

The server node (SN) set the value for each cluster. The value is relative to the node density in a cluster and ratio of the cluster heads in a WSN. It is the product of the number of nodes in a cluster and ratio r. The value can vary from 0.01 to 0.99 but it should not be more than 0.50. The lesser the value of , the greater the probability of getting a local optimal is. The value determines the number of best sensor nodes as candidate CHs. For each sensor node deployed in the cluster, we choose its nearest neighbors based on distance. The distance between sensor nodes can be calculated through received signal strength indicator (RSSI) that is described or any other localization technique . When the number of immediate (1-hop) neighbors is less than and distance is greater than the transmission range then multi-hop route is preferred. Multi-hop route is preferred over direct because of less energy consumption. The server node (SN) adopts the procedure detailed below in order to select candidate CHs for each cluster. The server node (SN) maintains a table for each cluster, listing all the sensor nodes present in the cluster. It maintains nearest neighbors for each node and the frequency of occurrence of each node is maintained in the table. The ordered list of sensor nodes based on their frequency is shown in Table. The minimum frequency required in cluster i to be the CH is calculated based on weighted mean of frequencies and 1 is added for better result. Weighted mean is calculated by product of each frequency of occurrence into number of sensor nodes having that frequency. The value is rounded to the nearest integer if required. The sensor nodes having frequency or greater are identified as candidates for CH.

VII. ENERGY CONSUMPTION MODEL

HEF provides optimal cluster head selection with respect to network lifetime under the ICOH condition[1]. Now, we are ready to address the key characteristic and the deterministic predictability for a hard network lifetime of WSN. The amount of energy consumed by a sensor node depends on the role it serves, as well as the workload it handles. To analyze hard network lifetime for guaranteed schedulability, the worst-case energy consumption (WCEC) analysis is used and the minimum energy consumed for a cluster head, and a regular node in a round respectively. In proposing HEF scheme, a total of nodes with the highest residual energy will be chosen to be cluster heads in each round. The rest of the nodes would serve as regular nodes. Each regular node joins the cluster formed by the cluster head closest to it. In each round, each sensor node sends the sensed data to its corresponding cluster, which forwards the information to the base station.

VIII. CLUSTER-BASED SENSOR NETWORK

There are two different kinds of sensors in the network. Sensor acts as the cluster head and other sensors play the role of cluster members[21]. The message transmitted from the cluster members to the cluster head are constrained to the bits. Each cluster member quantizes its observation to bits and sends the quantized data to the cluster head. The cluster head performs source extraction based on its own observation and the received quantized data from the cluster members

IX. CLUSTER FORMATION PHASE

In this phase, clusters are organized and cooperative MIMO nodes are selected according to the steps described below

A. *Cluster Head Advertisement*

Initially, when clusters are being created, each node decides whether or not to become a cluster head for each round as specified by the original LEACH protocol. Each self-selected cluster head, broadcasts an advertisement (ADV) message using non-persistent carrier sense multiple access

(CSMA) protocol. The message contains the header identifier (ID).

B. Cluster Setup

Each non-cluster head node chooses one of the strongest received signal strength (RSS) of the advertisement as its cluster head, and transmits a join-request (Join-REQ) message back to the chosen cluster head. The information about the node's capability of being a cooperative node, i.e., its current energy status is added into the message. If a cluster head receives the advertisement message from another cluster head y, and if the received RSS exceeds a threshold, it will mark cluster head y as the neighboring cluster head and it record ID. If the sink receives the advertisement message, it will find the cluster head with the maximum RSS, and sends the sink-position message to that cluster head marking it as the target cluster head (TCH).

C. Schedule Creation

After all the cluster heads has received the join-REQ message, each cluster head creates a time division multiple access (TDMA) schedule and broadcasts the schedule to its cluster members as in original LEACH protocol. This prevents collision among data messages and allows the radio of each non-cluster head node to be turned off until its allocated transmission time to save energy.

D. Cooperative Node Selection

After the cluster formation, each cluster head will select J cooperative sending and receiving nodes for cooperative MIMO communication [5] with each of its neighbouring cluster head. Nodes with higher energy close to the cluster head will be elected as sending and receiving cooperative nodes for the cluster. At the end of the phase, the cluster head will broadcast a cooperative request (COOPERATE-REQ) message, which contains the ID of the cluster itself, the ID of the neighboring cluster head y, the ID of the transmitting and receiving cooperative nodes and the index of cooperative nodes in the cooperative node set of each cluster head to each cooperative node. The cooperative node on receiving the COOPERATE- REQ message, stores the cluster head ID and sends back a cooperate-acknowledgement (ACK) message to the cluster head.

X. DATA TRANSMISSION PHASE

During this phase, the data sensed by sensor nodes are transmitted to the cluster head and forwarded to the sink using multi-hop MIMO scheme according to the routing table.

A. Intra Cluster Transmission

In this phase, the non-cluster head nodes send their data frames to the cluster head as in LEACH protocol during their allocated time slot. The duration and the number of frames are same for all clusters and depend on the number of non-cluster head nodes in the cluster.

B. Inter Cluster Communication

After a cluster head receives data frames from its cluster members, it performs data aggregation and broadcasts the data to cooperative MIMO sending nodes. When each cooperative sending node receives the data packet, they encode the data using space time block code (STBC) and transmit the data cooperatively. The receiving cooperative nodes use channel state information to decode the space time coded data . The cooperative node relays the decoded data to the neighboring cluster head node and forwards the data packet to the TCH by multi-hop routing.

XI. SCHEDULABILITY ANALYSIS OF HEF

The most important property of the WSN network lifetime is not longevity, but predictability. Schedulability tests are essential for the time-critical system because it provides predictability to complement online scheduling. Cluster head selection algorithms produced by empirical techniques often result in highly unpredictable network lifetimes. Although an algorithm can work very well to prolong the network lifetime for a period of time, a possible failure can be catastrophic, resulting in the failure of a mission, or the loss of human life. A reliable guarantee of the system behaviors is hence a requirement for systems to be safe and reliable. However, there are currently no known analytical studies on the network lifetime predictability for cluster head selection algorithms. Apply the worst-case energy consumption analysis to derive the predictability of HEF. The core idea of the HEF clustering algorithm is to choose the highestranking energy residue sensor as a cluster head.

A. HEF Algorithm

HEF selects the set of M highest ranking energy residue sensors for cluster heads τ at round where M denotes the required cluster numbers at round τ [1]. HEF is designed to select the cluster head based on the energy residue of each sensor to create a network-centric energy view. Intuitively, HEF is a centralized cluster selection algorithm.

B. Operation of HEF

The interactions and detailed operations between components are discussed as follows.

- HEF selects cluster heads according to the energy remaining for each sensor node, and then the "setup" message (indicating cluster members, and the cluster head ID for each participated group) is sent to the cluster head of each cluster.
- The cluster head of each group broadcasts the "setup" message inviting the neighbor sensor nodes to join its group.
- After receiving the "setup" message at this round, the regular sensors send the "join" message to its corresponding cluster head to commit to associate with the group.
- Each cluster head acknowledges the commitment, and sends TDMA schedule to its cluster members.
- All sensors perform its sensing and processing and communication tasks cooperatively at this clock cycle (round). Each sensor sends its energy information to its cluster head at the end of this clock cycle.
- Upon collecting cluster members' information at a given period, the cluster head sends the summative report to the base station.

XII. SIMULATION RESULTS

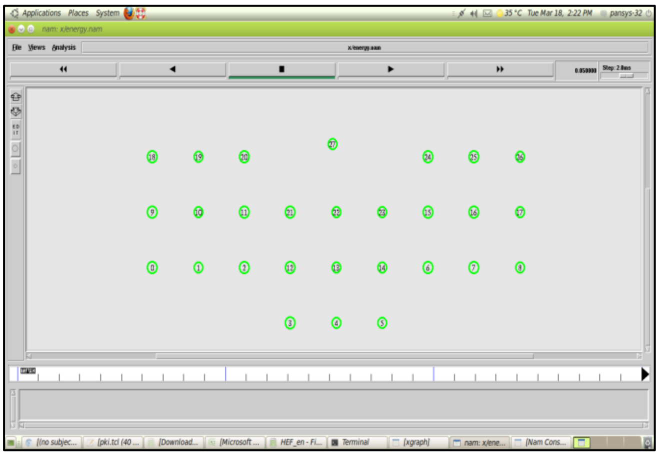

Fig. 3: Network Formation

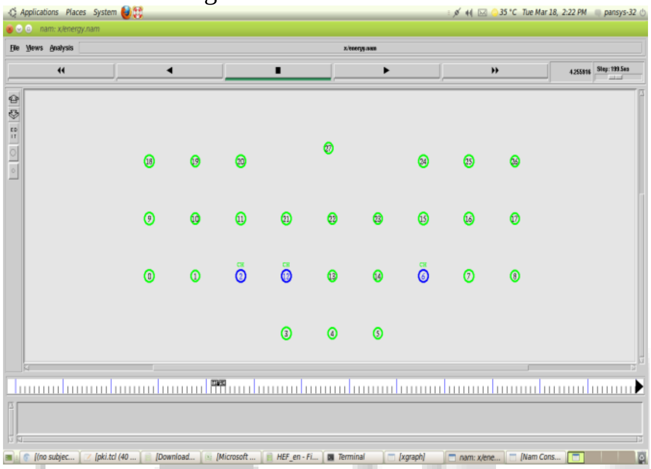

Fig. 4: Cluster Head Selection

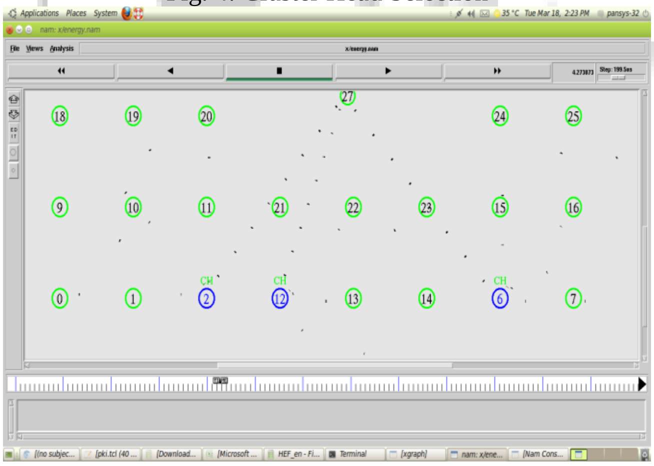

Fig. 5: Data to Cluster

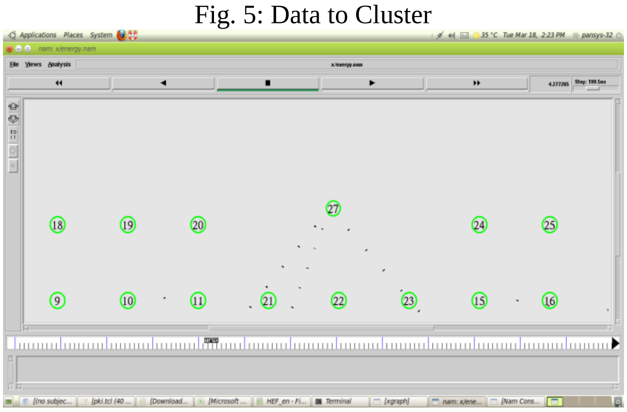

Fig. 6: Data to Sink

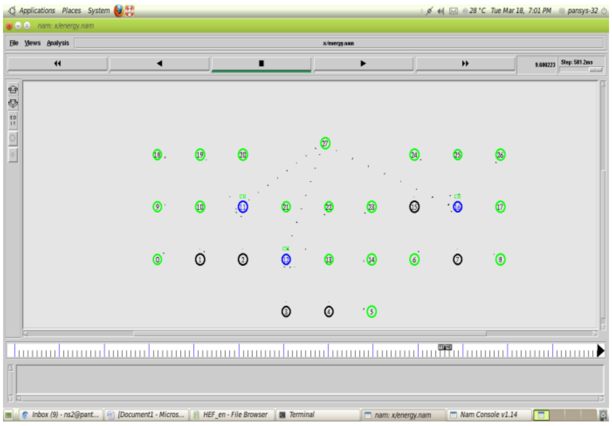

Fig. 7: Cluster Changes 1

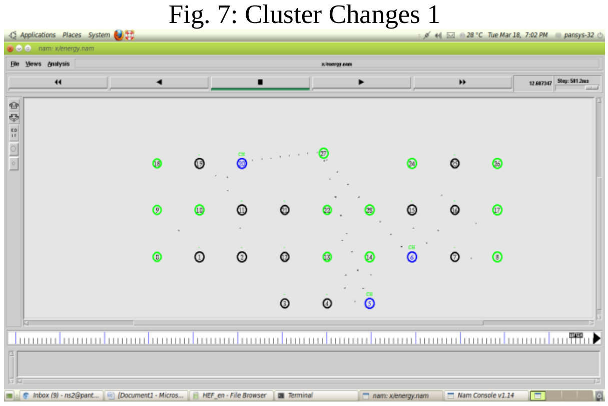

Fig. 8: Cluster Changes 2

XIII. CONCLUSION

We have addressed the issue of the predictability of collective timeliness for WSNs of interests. First, the High Energy First (HEF) algorithm is proven to be an optimal cluster head selection algorithm that maximizes a hard N-of-N lifetime for HC-WSNs under the ICOH condition. Then, we provide theoretical bounds on the feasibility test for the hard network life-time for the HEF algorithm. Our experiment results show that the HEF algorithm achieves significant performance improvement over LEACH, and HEF's lifetime can be bounded.

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