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Maximum Demand Control using Ad-Hoc Network to Avoid Grid Failure

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Abstract

Controlling and monitoring the electrical grids from theft of power and high usage of power than the allotted is difficult and hard. Considering the above problem, a real time system using wireless sensor network is designed that detects when a user crosses the load limit or a theft occurs in the power line. Power can be distributed more efficiently to industries without crossing the load demand. The maximum load usage is specified by the Electricity board - EB according to which this system is designed. Each current transformers and potential transformers are incorporated with the developed system and if in any line, more than the specified power is drawn then a buzzer is set and will turn off till the user reduce the power consumption. The same will be alerted to the electricity board about the power violation. If the load usage is not reduced by the user after the buzzer is set, then the particular line that overdraws power will be shut down and an alert will be sent to the EB office about the same preventing the shutdown of the whole system.

Keywords: Ad-hoc Networks, Maximum Demand Control, Power Grid Control, Radio Transceivers, Wireless Sensor Networks

1. Introduction

The largest power outage in India occurred on 30th July 2012 and power was restored back on August 1st. The three member investigation committee was assigned to investigate and issue a report on the cause for the outage. According to the report, there were four factors responsible for this blackout lasting two days.

- 400kV high loading.
- Lack of response on overdrawing power.
- Protection systems miss operation.
- Multiple existing outages causing weak inter regional power transmissions.

A real time system is developed considering the above mentioned issues and also to reduce the number of power theft. This issue can be greatly avoided in the future and the huge amount used in the restoration of power can be saved. Load supplied to the industries can also be monitored which at present is a great issue.

A sensor based system is developed to measure the load drawn by the user. A comparison is done between the loads drawn to the maximum load specified by the EB. If the load exceeds the specified load then a warning is issued to the user as well as to the EB office. The user must respond to the warning immediately.

The buzzer triggers the timer in the system. If the user fails to respond to the issue then the system itself handles the situation by tripping the load that draws excess power. This avoids the whole line shut down or any power outages. Only the authorized person can later turn on the supply after necessary steps taken.

Malicious activities, electrical disturbances, faulty structures and extreme natural conditions like high wind, temperature can be monitored and the loss occurring due to this can be greatly reduced. This ensures that everyone gets their fair share of electricity without any discrepancy.

Monitoring the power lines are based on wireless sensor which considerably reduces cost and gives remote control to the EB. This also solves problems like real time

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structural awareness, localization of faults are faster and fault identification is more accurate giving clear picture of electrical faults which requires condition based maintenance from mechanical malfunctions that requires periodic maintenance.

Wireless sensor based network are already implemented in gird monitoring for any failures, rating application for transmission lines etc. which makes it easier to implement in this application. Remote monitoring in wireless sensor is also an added advantage.

The network should be able to transmit high amount of data fast and accurate. The data received in the EB should be highly reliable with less or no error and with very minimum time delay. The real time system is designed that efficiently does all the tasks and also care is taken that the system is developed using minimum cost. External Disturbances and practical issues are considered while developing which makes the system to give more accurate results under various circumstances.

2. Related Work

The communication between the main office – EB and the nodes is the primary analysis which should be done effectively and efficiently considering the cost and data latency. Different approaches are discussed and systems are developed for the above purpose by considering the communication medium.

Table 1. Technologies and its characteristics

Properties	Cellular (3GPP LTE)	Wireless (Zigbee IEEE 802.15.4)
Type of Link in Network	Transmission towers to cellular towers	Between towers or Between tower and substation
Bandwidth	Uplink 75 Mbps, Downlink 100 Mbps	250 kbps
Delay	≈ 50 msec	≈ 16 msec
Transmission Range	100m - 10km +	10m - 1.5km
Installation Cost	≈ 25x-50x	≈ 1x
Operational Cost	≈ 5x-20x	≈ 2x
Channel Contention	No	Yes
Subscription Fee	Yes	No

The proposed paper[3,4] uses the cellular network for transmitting the messages. The system effectively does the task by alerting the EB but deploying this system is very costly as it involves cellular network. The sensors used in this communicate with the call tower in order to transmit data. It gives high data transmission rate and high bandwidth. This system is not deployed due to the following reasons.

- The network is considered to be symmetry and available all the time. This consideration is unrealistic due to

a. Less cellular coverage area due to the unavailability of towers.

b. Difference in data rate transmitted by the towers with respect to the location.

c. Certain region may have irregular terrains due to which the wireless devices are denied forcing the use of cellular network alone.

- In this analysis, minimum delay is considered as the primary factor. Design cost is discussed in the paper but fails to mention the deployment and maintenance cost of the cellular transceivers which is the main drawback.
- The mathematical terms which involves a quadratic equation whose roots are rounded to an integer to get the number of towers to be deployed is stated. This rounding off affects the bandwidth and latency which is not considered while deriving the equation.

The above points make it less implementable. Later the authors of[4,5] proposed an asymmetric model that involves both cellular as well as the optical fiber cable that is already deployed and in use in the transmission. Thus cost of implementation is less. The data are transferred using the optical fiber and when line is not available the data are transferred to the cellular network. Table 1 shows the comparison between two systems.

The asymmetric communication provides high bandwidth and latency and also the cost of implementation is less. This sure is an advantage but the algorithm involved is difficult and hard to understand. Complex algorithm, more equations and derivations makes it hard to implement.

In this paper, all the above advantages and disadvantages of existing systems are considered and a suitable real time is developed that is efficient in performing the task, implementation is easy and with less cost of implementation.

The system designed to measure the potential difference is implemented with the wireless module. The data is transferred to the EB office using the Ad-hoc method. The communication is established between the modules or nodes or motes with the coordinate by hoping from one mote to another established. The algorithm decides the path to be taken to the coordinate mote.

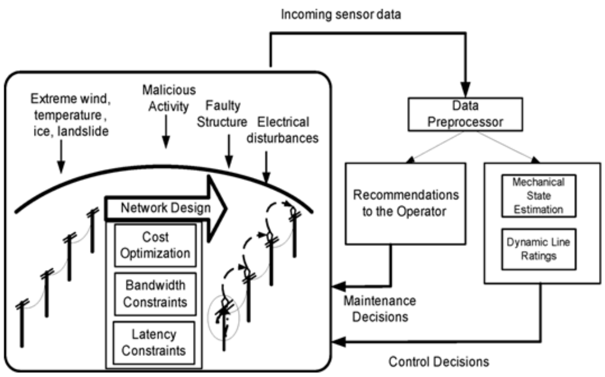

Figure 1. Framework of sensor network.

3. Hardware Set-Up

The system proposed in this paper is a symmetric model in which the communication purely takes place between wireless modules. After a detailed study about the wireless sensor Zigbee, IEEE 802.15, is used in this system since it provides greater coverage area and bandwidth. Zigbee uses 2.4 GHz ISM band with 16 channels of 5MHz bandwidth. The on-air date rate for Zigbee is 250 kbits/s per channel for 2.4 GHz.

The communication between Zigbee is controlled and monitored by microprocessor. Figure 2 Reference mote system setup. The reference mote system is implemented with a current sensor and potential sensor. Current sensor measures the amount of current drawn and potential sensor is used to measure the potential difference in voltage. The supply is in terms of current and hence current sensors deployed.

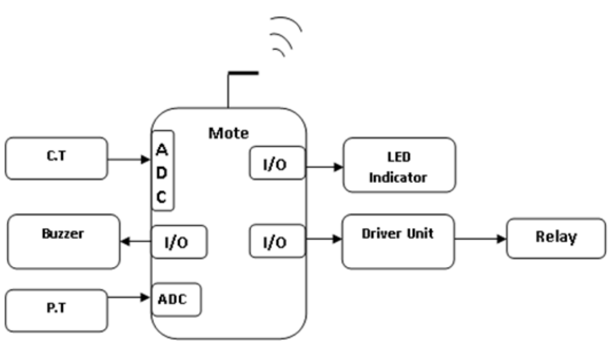

Figure 2. Reference mote system.

The consumption by user is in the form of voltage. The main aim is to measure the excess amount of voltage used by the user than the specified voltage. Hence a potential difference is deployed that will measure the difference of voltage between the used level and specified. The sensors are monitored by the microprocessor which is also connected to buzzer and relay.

Buzzer and relay are set once the user exceeds the specified value and comparison of the value is done by microprocessor. The coordinate mote consists of has microprocessor and buzzer as well to alert the EB office when power is overdrawn. The coordinate mote is implemented in EB as the reference mote is deployed in the transmission line. Figure 3 shows the coordinate mote system setup.

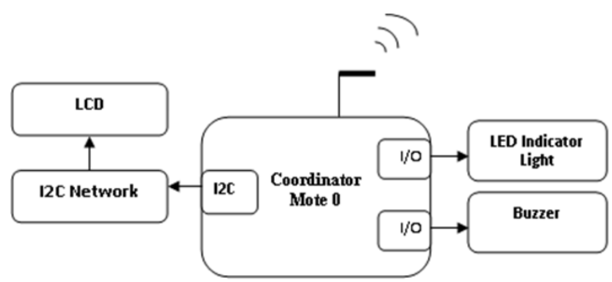

Figure 3. Coordinate mote system.

The sensor values are compared and once the value hikes above the specified value, required that both the sensor values crosses the values, the buzzer is set for a predefined time. If the user does not reduces the load then the system trips off the line that exceeds the value. The above action is also informed to the EB. By taking both the sensors into account the unnecessary alarming due to other faults are avoided. Also the reinstallation costs are avoided by isolating and cutting the extra load alone.

4. Algorithm

The term neighbor node refers to the node that is present close and in the wireless transmission region covered by a node. The term neighborhood is used in this paper to denote the nodes that is present in the wireless coverage area. Dijkstra algorithm is adopted for transmitting the signal in the shortest and desirable path.

4.1 Information Routing

The data transmission occurs only when the user exceeds the specified value. The data should reach the EB office as soon as the line is tripped by the system and hence high priority should be given to it. The path taken by the data should be minimum and with less hop count. Different scenarios are considered that should be taken into account while designing the network and routing path.

- Maximum hop count with maximum distance should be avoided so minimize delay and loss of date. The data transmitted is delay sensitive and of high priority.
- Minimum hop count with maximum distance should also be avoided as the delay is reduced but the increase in distance results in loss of signal or addition of noise or error. This however can be taken as an option when the line is congested or failure occurs.
- Maximum hop count with minimum distance is a more opted option than the above during failure of a line or high traffic. The maximum hop count may lead to delay of data but that is acceptable to a certain level when compared to loss of data as in above case.
- The perfect way is fixed by considering minimum hop count and minimum distance. Data is routed in this path with minimum delay and minimum error.

The algorithm is designed according to the above said points. The routing of data from source to destination is shown in Figure 3. The routing is based on dynamic routing protocol. That is the data does not follow a fixed path. Each time a data is transmitted the path is determined by referring the routing table that has minimum hop count and distance.

When the network is set up the nodes communicate with each other by sending a test packet. Figure 4 shows the path calculation and updating the routing table as a result. The source packet sends a packet to each path that it is connected with. The motes or nodes update the hop count by 1 in the routing table of the packet. Once the packet reaches the destination, the nodes end the packet again to source that via the path that has least hop count. Thus the node updates its path information and routing table.

The dynamic routing of data has an added advantage in the times of high traffic or failure of a link. When there is a node misbehaving or congested with data or failure of node may lead to loss of data. By dynamically routing the data each time to the destination the loss of data due to undesired or unexplained situations can be avoided.

However there will be delay in data reaching the destination due to dynamic routing as the path in which the data should be transmitted is determined each time. Time taken each time can be avoided using fixed path routing but the failure of link or during congestion may lead to loss of data. Hence this method is much suitable for this application as loss of data cannot be tolerated.

The motes when get an alert to transmit data, using their transceiver it transmits and receives the signal. The strongest signal that is received from the node is determined and the node shares its routing table and the number of hop counts are determined. If the number of hop counts is lesser than the number of hop counts in its routing table. If not then the signal with the second strongest signal and the process is repeated.

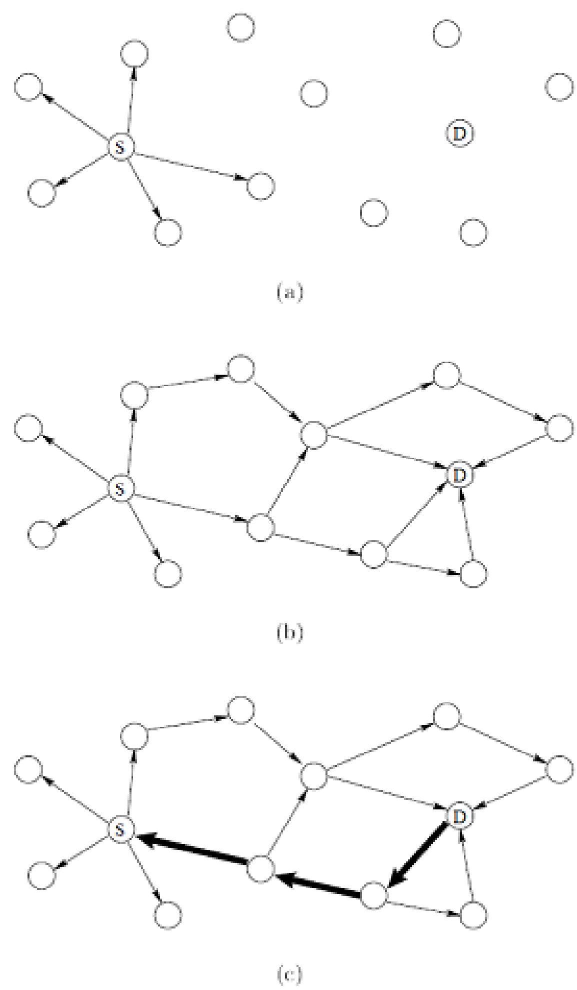

Figure 4. Shortest path calculation by sending a packet from source node S to the destination node D. For each node the hop count in the routing table is incremented by 1. The destination node sends the packet back to the source node via the path that has least hop count.

The Received signal strength indicator- RSSI and link quality indicator- LQI also plays an important role in determining the path. Depending on the RSSI value and LQI value the path is determined. High RSSI and high LQI shows that the mote is the nearest and noise is minimum.

5. Estimation Model

The estimation for the path is done with the help of the pre evaluated equations that are modified and refined for this particular application. The estimation is done as given in the following steps

- The reference motes values in its communication range are collected by the user mote. With the help of that value least hop count is determined and decides the next destination and the data is transmitted to the reference mote.
- At the end of each step, Power is calculated and compared with the threshold Power value. If the calculated Power is greater than the threshold power value then the data continues to move towards the same direction.
- If the user mote detects lesser hop count than the current reference mote then the reference mote is changed to the lesser hop count and follows from the step one.

RSSI is the RSSI value at distance X and $RSSI_0$ is the value at distance X0, β is the path loss factor and X is the zero mean Gaussian noise, X0 is the short distance between transmitter and receiver.

$$RSSI = RSSI_0 - 10 \times \beta \times \log (X/X0) + X$$

The power is calculated by the following equation that uses the two's complement of RSSI value- RSSI [OFF].

$$Power = RSSI\,[VALUE] + RSSI\,[OFF]\ [dBm]$$

The closest distance with the minimum hop count should be considered which is calculated with the help of following equation. Though the value is not accurate but estimated value gives the path that is closest to the destination. n is the path loss factor and fm is the fade margin defined as the sensitivity of the receiver to the received signal. Power transmitted at distance X0 and X is given as pt and pr respectively. Fr is the frequency of the signal. The equation is given as follows.

$$Distance = 10[(pt\text{-}fm\text{-}pr\text{-}10 \times n \times \log_{10} fr+30 \times N\text{-}32.44)/10 \times N]$$

The noise in the medium plays an important role in determining the distance. Although several equations are derived for calculation of distance none of it shown effective in calculating distance. Since this application does not require accurate value of distance an approximate value can be determined.

Also the distance is calculated only for the newly installed sensors, as the already installed system has the distance pre-programmed in it. This reduces the complexity and also the calculation of the distance is one time process and it is saved in the routing table for future use.

6. Test Preparation

The system is programmed according to the above algorithm and installed in the transmission line. The distance to which it is installed is a known factor and accordingly the routing table is updated. When a new system is installed the routing table of already existing system is updated using the above giving equations.

The systems communicate with each other and based upon the RSSI value the distance is calculated. The mote then exchange their calculated distance and thus approximates its distance by comparing the distances calculated by other motes and pre-determined distances in the routing table with the existing mote.

The system is connected and tested several times to observe the path taken by the data to the destination EB office. Depending on the external factor like wind and temperature, the sensors receives different RSSI value due to which the path taken is not constant.

During congestion and link failure, data follows different path ensuring that the data is received without any loss but with considerable delay. The system does not ensures that the path taken by the data is shortest path but do ensures that the data reaches destination. External conditions like wind, rain, temperature becomes the path determining factors.

7. Conclusion

The proposed system works well under pre-determined circumstance however when the external factors becomes more influential, the behavior of the system is undetermined. The coverage area of the system is less due to the sensors deployed when covered to the cellular systems but installation and maintenance cost favors this system.

The symmetric nature of the system makes the system easier to use and maintain which does not require more technical knowledge and training. The algorithm implemented is also is easy to develop. The most important feature of this system is flexibility. The system adapts itself to the newly installed system and updates its routing table which does not require any special programming or update.

The automatic tripping of line is the advantage of the system which does not wait for an official to notice it and also avoids any shut down of the whole line or power outages due to this. Thus lets everyone to use their fair share of electricity without anyone misusing it. However the only limitations to the system is that the result produced is dependent on the external factors.

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