Design and Development of A Simulation Frame Work For WSN Based Moisture Deficit Monitoring And Control In Irrigated Agriculture

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Abstract- The dependency of economy of many countries on irrigated agriculture demand a high level precision in water supply and regulation to save water and incurred cost. The technology of Wireless Sensor Networks (WSN) seems to give a possible solution for this. However before such technologies are applied we need to have simulating environment and tools to foresee the strategies of implementations. There are some simulators available that help to simulate various networks. However for simulating Moisture Deficit Monitoring and Control in Irrigated Agriculture, there is a need to for typically designed and developed simulation application framework. This paper presents a complete simulation application framework created in ns2 simulation environment considering all parameters and possibilities. A WSN cluster-based approach is used for the simulation. The class hierarchy is developed and tested with tcl scripts of ns2. It deals with sensed soil moisture data, its routing, aggregation, Processing and relay to the sink. Both On Demand and Event based approaches are taken in consideration. The application will finally give a real situation of soil moisture and distribution in the field and will help in quantifying the supply and irrigation scheduling.

I. Introduction

Wireless Sensor Network has opened new avenues to deal with the problems which require accurate and time critical solution. It also helps in achieving the complete automation of the systems which require manual interference at present. The irrigated agriculture is an area which requires precision in calculating the water demand of the crops, dynamic regulations of water supply channels like pipes or canals. WSNs have been already deployed in various aspects of agriculture and results are found encouraging.Several network simulators exist at present which give a simulating environment and tools to foresee the strategies of implementations before it is applied in the field. As available simulators do not provide all the desired functionalities for simulating typical application of moisture deficit monitoring and control in irrigated agriculture, a simulation application framework has been designed and developed and presented in this paper.

In the application framework a complete class hierarchy is developed for node, applications on node, routing protocol , aggregation , processing and Data Generation and dissemination. Lower level link and Mac layer issues are also addressed by them. The complete application is written using ns2 classes and simulation is written in TCL scripts. Sample runs and results are also done with analysis of some popular protocols suitable for this problem.

1.1 Related Work

Bartosz Muszniki et all [1] has discussed various simulation environments and commented on the criteria of their selections,. The problem in consideration required a cluster-based approach of WSN.

B.Manimekala and M.Kayalvizhi [2] used ns2 simulator to test their problem of WSN using AODV routing protocols. Young-guk Ha et al [3] have also used ns2 to simulate the problem regarding fire-tracking. A new PHONEM packet structure is also proposed to deal with clustered base approach, however it is not problem specific but very generic way to deal with cluster based routing. Balendonck, J et al [5] have used WSN in the deficit agriculture but it was a practical approach rather than a simulation. The problem of moisture deficit monitoring and control in irrigated agriculture problem is quite specific application area for which above simulator set up cannot be used as it is. The problem demands rewriting of the simulation classes, strategies, and deal with routing and aggregation in a new way. The study of various

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routing and aggregation schemes [10,11,12,13] revealed that TEEN and APTEEN [13] are nearest ones which can be modified for our purpose. The Mannasim framework which deals with clustered network and simulates LEECH routing protocol formed the base for the simulation for the current problem.

1.2 Organization of the Paper

The paper describes complete design and development of a simulation application frame work for WSN based moisture deficit monitoring and control in irrigated agriculture. The paper is organized in following sections:

2. Terms and Definitions
3. Simulation Scenarios for Irrigated Agriculture
4. Design & Development of simulation Application Framework
5. Results
6, Conclusion

II. Terms and Definition

As the simulation is done for the irrigated agriculture, some of the important terms in this area are as follows

1. *Drip and Sprinkler irrigation* : This a pressurized irrigation technique in which the water is supplied to the pipes under pressure in order to deliver it on the pre designated positions of crops. This can be in the form of continuous drops (as in drip irrigation) of jets or sprinkles (as in sprinkler irrigation). This technique is most suitable for row crops and orchards
2. *Gravity Irrigation* : In this technique the water is allowed to flow under influence of gravity in the network of open channels like canals and delivered to the fields. The are most suitable for cereal, pulses and oilseed crops
3. *Mains* : It is the main pipe with high discharge capacity which caries the water to be distributed in smaller pipes.
4. *Manifolds* : The water from the mains is delivered in lesser capacity pipes called manifolds
5. *Laterals* : They are the final delivery pipes which reaches to the fields
6. *Drippers and Nozzles* : They are the final outlets which deliver water to the crop
7. *Irrigation Command* : The whole area which can be irrigated by a water storage structure like Dams, Weir and Barrages. The reservoir full water level decides the maximum irrigation command which can be covered under gravity irrigation
8. *Chak* : An irrigation command area of approximately 40-50 ha and is a unit of irrigation area in command to be served by an outlet on minor
9. *Subchak* : A part of chak of 5-8 ha of area approx to be served by outlet on sub-minor
10. *Irrigation Reservoir* : A huge water body created in the upstream of obstruction created naturally or manually on natural streams like river
11. *Main Canal* : The canal exiting from the reservoir head serving the discharge requirement of Branch canals
12. *Branch Canal* : The canal exiting from outlets of main canal serving the discharge requirement of Distributories
13. *Distributories* : The Canals exiting from outlets of Branch Canals serving the discharge requirement of minor
14. *Minor* : The canal exiting from outlets of Distributories . A water delivery canal which can irrigate an area of approximately 8-10 chaks
15. *Subminor* : The water delivery canal irrigating whole chak with its out lets at head of subchaks. This canal is lowest in the hierarchy and is doing the end delivery of water to fields
16. *Irrigation Interval* : The frequency by which water is supplied in the fields, it is fortnightly in India using Rotational Water Distribution System. Fig 1 describes the conceptual infrastructure of the irrigation command.

III. Simulation Scenarios for Irrigated Agriculture

The controlling factor to supply water in pressurised and gravity irrigation is the soil moisture deficit which needs to be replenished by supplying water. In order to achieve the complete automation and dynamic regulation of delivery network, the information of soil moisture stress should be supplied in the real time. A Gypsum based Soil moisture meter (manufactured by Irrometer) sensor has been interfaced with ZIGBEE MICAz wireless sensor . This sensor can sense the soil moisture deficit and relay the deficit to the control centers wirelessly. This simulation tries to understand and create a complete application framework where different strategies and scenarios like sensor layout , packet routing , data aggregation and energy dissipation can be tested so as to optimize the real implementation. Following figures suggest possible scenarios for which the simulation Exercise is undertaken

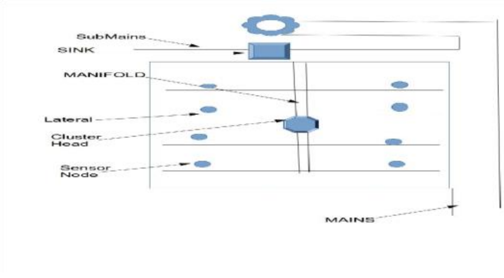

Fig. 3.1 : Sensor Layout for Drip Irrigation

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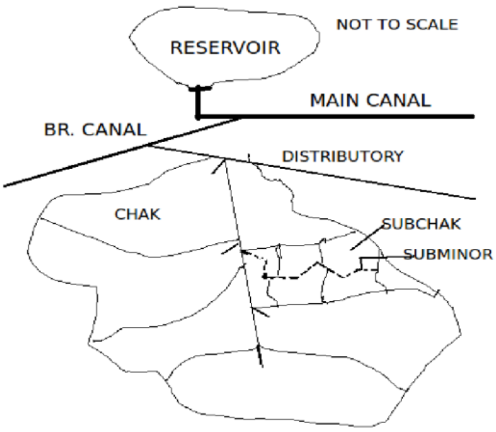
3.1 A Wsn Scenario For Drip IrrigationIn fig. 3.1 Soil moisture sensor nodes are placed at 2/3rd of the length of laterals from its offtake. One manifold will have one sink node where all Sensor nodes are sending the data packets. This sink node can be equipped with a GSM interface to report the data to the discharge controller. The data acquisition can be query based as well as Event based.

3.2 A WSN Scenario for Gravity irrigation



Fig, 3.2 WSN LAyout in Gravity Irrigation

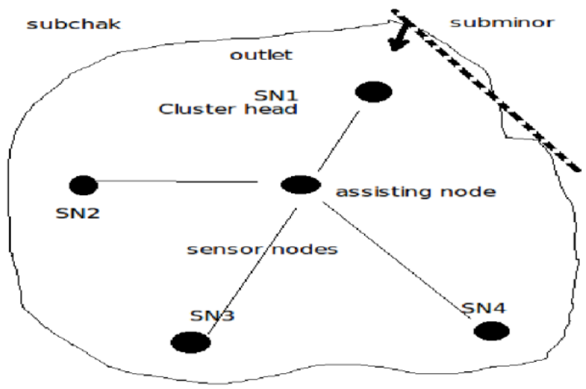


Fig. 3.3 Sensor Layout in a chak

In the fig 3.3 SN2 SN3, and SN4 are the soil moisture sensor nodes while SN1 is the cluster head . If the chak is very large then assisting nodes can be placed to send the data packet to cluster head. Inter-cluster distances are very large so a cluster is also equipped with a GSM Module to receive and send the data to the sink which can be placed at the head of minor. The data acquisition will be query based and event based

VI. Design & Development of Simulation Application Framework

The simulation framework was needed to simulate following functionalities of implementation

1. Soil Moisture Sensor Node
2. Soil Moisture Sensor Cluster Head Formation – Dynamic as well as Static
3. Data Acquisition and Dissemination
4. Link and MAC Layer Representation
5. Data Packet Formation
6. Data Packet Routing
7. Data Aggregation
8. On Demand Soil Moisture Data Acquisition
9. Event and Threshold Based Soil Moisture Data Acquisition
10. Energy Measurements
11. Generating Trace File Structures for all events in WSN 4.1 Class Structure in Application

The existing class structures of ns2 is utilized in developing new classes. The Mannasim Frame work [14] patch for cluster-based WSN is also used to scale ns2. As our application required special treatment in all the functionalities mentioned above the logic and class hierarchy was created for the same . The class hierarchy is described as under

location of files : ~/ns2.35/irrigation/application/. All the classes have their own Tcl Linkage with the same name

a) *SMSensorNode.cc* : is used to simulate a Soil Moisture Sensor Node. It contains class SMSensorNode < (inherits) SensorNode (of Mannasim) < MobileNode < Node of ns2. The node caries data like sensing power, processing power, instructions per second, Battery power .
b) *SMSensedData.cc* : This class SMSensedData is an encapsulation of the Soil Moisture data It contains a generic structure of AppData and an ArrayList to store the series of Data Packets
c) *SMSensorBaseApp.cc* : The class SMSensorBaseApp < Application represents the application mounted on the Sensor Nodes which has functionalities to trigger the data acquisition on demand and event and dissemination. It has the command to start, stop and collect the data in a SensedData ArrayList.
d) *SMCommonNodeApp.cc* : The class SMCommonNodeApp < SMSensorBaseApp represents a common data acquisition node. Which sense the data and route it to the Cluster Head
e) *SMClusterNodeApp.cc* : The class SMClusterNodeApp < SMSensorBaseApp represents the cluster head. It gets the data from common node and perform Aggregate operations. The data from the cluster head goes to sink via ZIGBEE radio-link or GSM transceiver. The provision of both has been made into it. The

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simulation script will have facility to attach GSM or not.

f) *SMAggregateProcessing.cc* This class SMAggregateProcessing < Processing will be responsible to do the job of aggregation depends upon the query parameter or event diagnosed

g) *SMDataGenerator.cc* The class SMDataGenerator < DataGenerator is the way to simulate the data sensing of the sensor node. The Generator can be configured for the time interval of sensing, buffer to be maintained. The Application classes like SMCommonNodeApp and SMClusterNodeApp will be accessing the buffer filled up by the SMDataGenerator and will forward it to Aggregate Processing.

h) *SMOnDemandData.cc* : This class SMOnDemandData < SMSensedData < AppData is a buffer to be loaded when a query is fired from the sink to know the current status of Moisture level in the area concerned

i) *SMRoutingAgent.cc* : This class SMRoutingAgent < RCAgent < Agent is used to forward the data to Demux Address and Demux Port to destination Address by sending them to lower network layer i.e Link Layer , Mac Layer , NetIf and PhysicalLayer for Radio Relay. The SMRoutingAgent uses modified TEEN and Modified APTEEN routing protocol. The class has facility to dynamically switch to LEECH for dynamic cluster formation. In case of threshold based routing Modified APTEEN is being used.

j) *SMAccessPoint.cc* : The class SMAccessPoint < AccessPoint represents the sink node. This class is responsible for gathering the data from cluster head . Proceeing the soil moisture data, Perform discharge calculations on them and sends it to

4.1 Working of Simulation

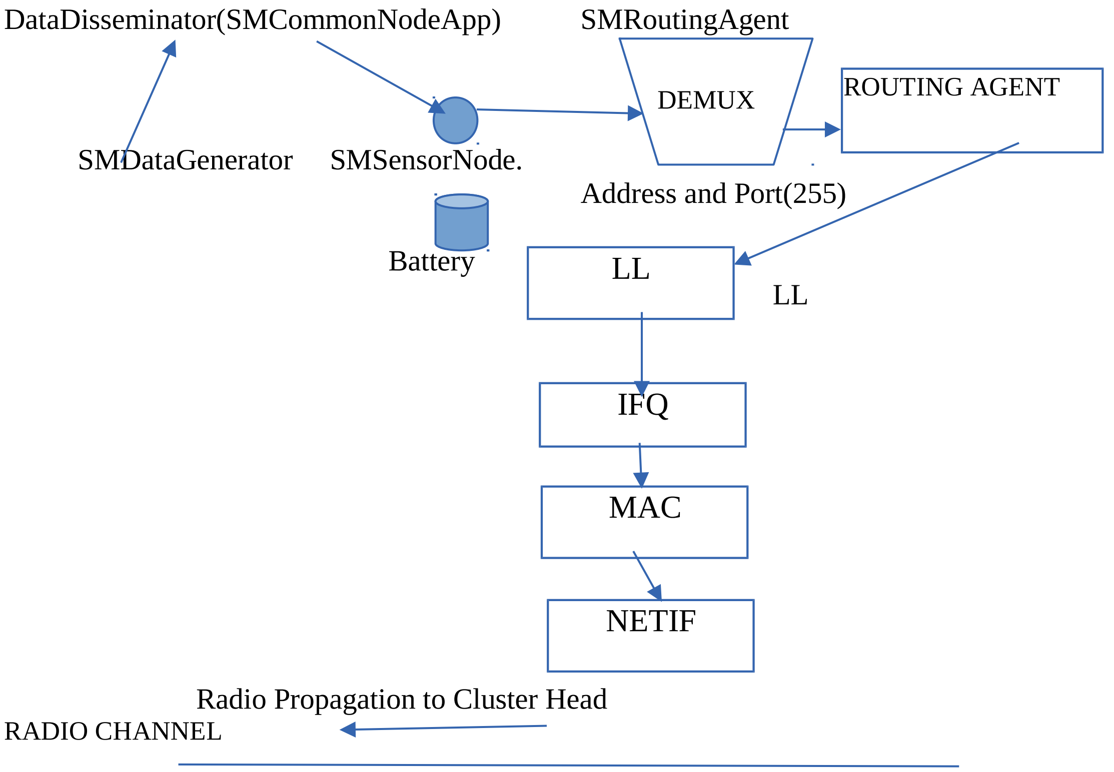
discharge controller of Pump or gate opening sensor in canals

k) *SMSensorGSMLL.cc* This class SMSensorGSMLL < LL is actually the translation of packet data from ZIGBEE Specific Link Layer to GSM based Link Layer and vice versa. The Mac Layer of GSM gets the data directly from GSM Link Layer. The data from sensor is transfered from ZigBee Sensor to the GSM Module by attaching the module to ADC Pins This class is useful only in cluster head or Sink node and useful in Inter-cluster and inter-sink transmission

l) *battery.cc :* Here the Battery class of ns2 is used with input power configured in TCL script

The classes described here work in coordination with each other with to solve the problem . Following is the schematic representation of important tasks

a) Working of Soil Moisture Sensor Node



b) Data Aggregation : SMCommonNodeApp

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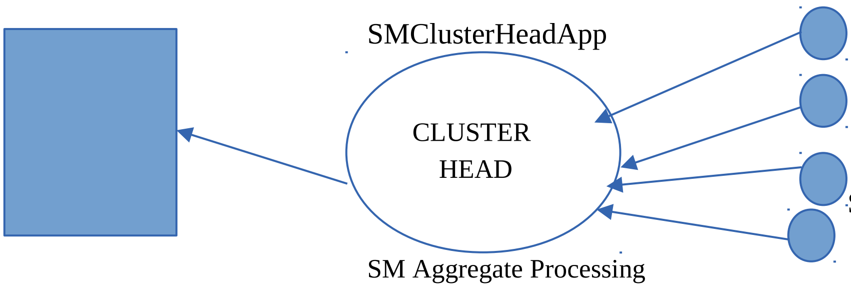
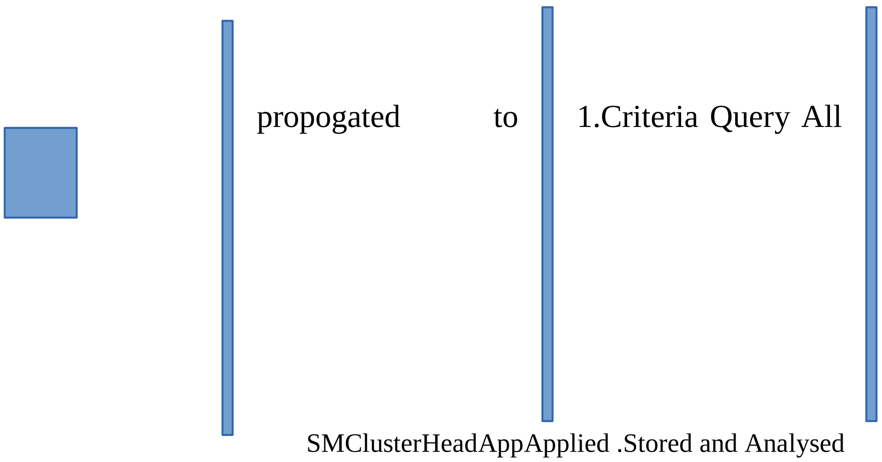
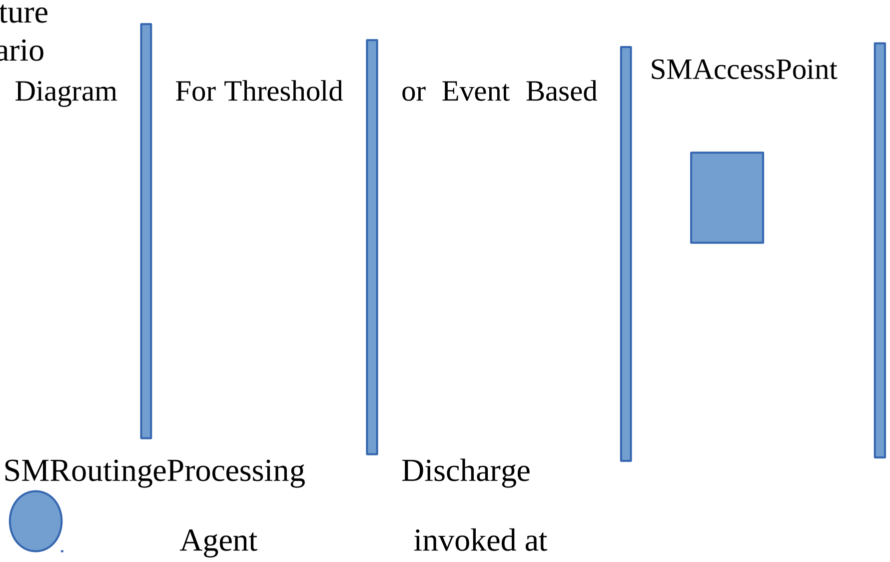


c) Sequence Diagram For On Demand Data



Sink Asks Soil Moisture Scenario
Sequence Diagram For Threshold or Event Based



4.2 The Simulation

With the above mentioned application framework the simulation is carried out on drip irrigation with

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50, 75,100,125,150 sensors and 5 Cluster heads and 1 sink node. In case of Gravity irrigation 10 chaks with 5 subchak each and one sensor representing one subchak which 50 sensors 10 cluster heads and one sink on minor head is carried out. The The General Network Topology Parameters are,

- Channel Type: Wireless Channel
- Radio-Propagation Model: TwoRayGround
- Network Interface Type: WirelessPhy/802_15_4
- MAC type: Mac/802_15_4
- Interface Queue Type: DropTail/PriQueue
- Link Layer Type: LL
- Antenna Model: Omni Antenna
- Queue Length: 50
- Network Layer Protocol: AODV/DSDV/DSR/APTEEN/LEECH
- Size of the Topography: 700 X 500
- The Constant Simulation Parameters are,
- Active Data Senders: 75% Sensor Nodes
- Sensor Data Size: 64 Bytes
- Fused Data Size: 512
- Sensor Data Interval: 1 Data Packet per seconds
- Channel Error Rate: 0.15
- Total Simulation Time: 10
- The Variable Simulation Parameter has Total Sensor
- *Nodes : 50, 75, 100, 125, and 150*

With above parameters the TCL script is written for the above simulation parameters . The task of simulation is accomplished by running the Tcl file and storing the output in trace files. Analysing Trace files using a tool trace-analyser.

V. **Result**

Following parameters were analysed and studied for testing the efficacy of the system.
1) Packet Delivery Ratio vs no of Nodes for different Routing startegies
2) Energy Consumed Vs No of Nodes for different routing protocol
3) Routing Load vs no of Nodes for different routing protocols
5.1 The Result Matrix

Table 1. No of Nodes vs Packet Delivery ratio for different routing strategies

Sr. No	No of Nodes	Packet Delivery Ratio		
		AODV	LEECH	SMRouting
1	50	99.13	99.45	99.76
2	75	90.37	91.14	92.35
3	100	83.78	84.25	85.21
4	125	72.92	73.19	74.54
5	150	64.88	66.18	69.97

Table 2. No of Nodes vs Energy Consumed in % for different routing strategies

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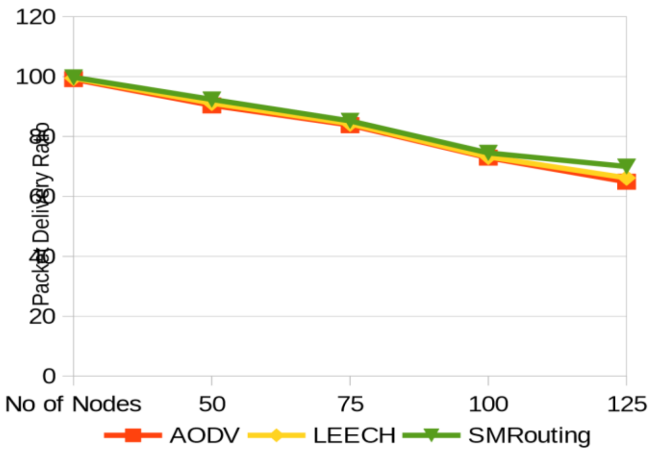
Sr. No	No of Nodes	Energy Consumed		
		AODV	LEECH	SMRouting
1	50	98.88	99.45	99.76
2	75	96.75	98.33	99.01
3	100	92	93.55	94.20
4	125	88	90.77	91.11
5	150	86	88.45	90.05

Table 3. No of Nodes vs Throughput for different routing strategies

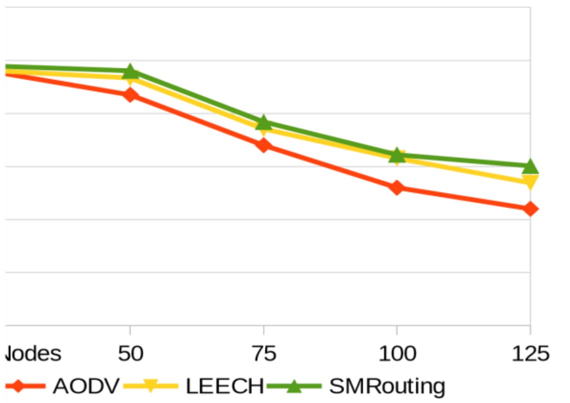
Sr. No	No of Nodes	Throughput		
		AODV	LEECH	SMRouting
1	50	10012	12235	13456
2	75	18238	19867	20110
3	100	21002	21878	22054
4	125	25014	26000	26945
5	150	31256	31987	32549

5.2 Graphs

Graph.1 Packet Delivery Ratio vs No of Nodes



ph 2 :%Energy Remained vs No of Nodes



Graph 3 : Througput vs No of Nodes

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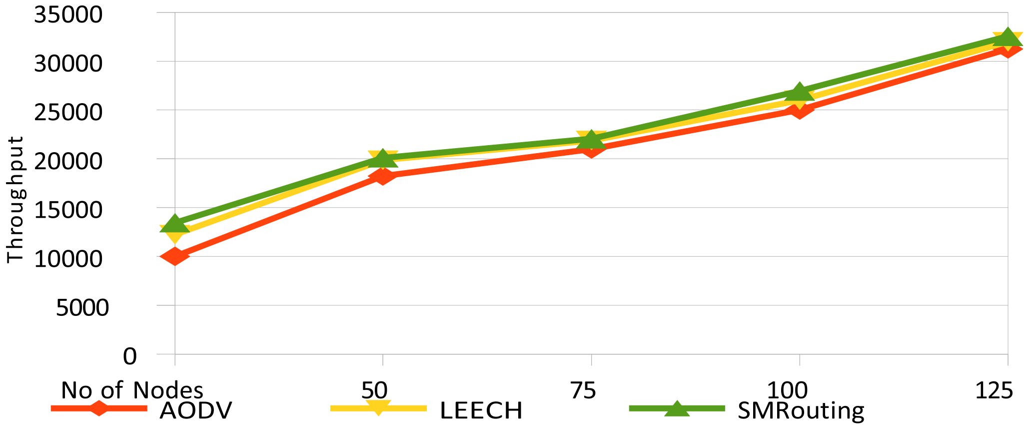

VI. Conclusion and Future Work

The Tcl simulation files using the newly developed application framework are run on ns2 console and correspoonnding trace files are generated from the run. It is quite evident that the new application framework successfully runs the new as well as pre-existing configurations and protocols. Although a comprehensive test run is required to test the appropriately modified routing and aggregation strategies suited for simulated WSN for irrigated agriculture. The GSM Module is still not tested in the application. The energy loss by GSM Link layer translation is not accounted for in the current paper. In future GSM interface should be also taken in account . As the packet transfer in not so frequent in this problem hence MAC layer can be made to have more slot time.

The existing MAC can be modified for this purpose.

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