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Multi-Agent based Context Aware Multipath Routing in Wireless Multimedia Sensor Networks

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Abstract: *Conservation of energy and delivery of multimedia information such as image, video and audio data in a stipulated time is one of the major concerns in wireless multimedia sensor networks (WMSN). Unlike wireless sensor networks which senses and communicates scalar data, WMSN senses multimedia data which is helpful in surveillance applications such as monitoring of military, agriculture, infrastructure, and so on. In order to tackle this issue of conserving energy and thereby ensuring longer network lifetime, this paper presents the agent based context aware multipath routing in WMSN. The proposed scheme considers various contexts based on the type of data sensed and then using software agents, multiple paths are discovered to send the sensed information from the event detected node to the sink node. To evaluate the performance of the proposed scheme, this work is simulated using NS2. Some of the performance parameters considered in this work is packet delivery ratio, Latency based on context type, energy consumption and number of paths discovered.*

Keywords: *Context Aware Computing, Multipath Routing, Software Agent, Wireless Multimedia Sensor Networks.*

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I. Introduction

Wireless Multimedia Sensor Network (WMSN) is network of sensor nodes enabled with low and high resolution camera, mike and other scalar sensors which senses multimedia data and communicates the same to the sink node. WMSN are widely used in applications such as monitoring in military, agriculture, forest fire, infrastructure, environment, traffic, elderly monitoring, patient monitoring and so on. In all such monitoring applications, the information sensed is of multimedia type. To transmit multimedia type of data, lot of energy and bandwidth is consumed during multi-hop communication in the network thereby reducing the network lifetime.WMSN poses certain challenges to be considered for designing the routing schemes. They are: (1) Source coding multimedia data: Multimedia data such as image, audio and video that are sensed need to be processed and transmitted as transmission of raw data does not take care of redundancy in images and videos, thereby consuming more energy and bandwidth of the network. (2) Specific QoS required by applications: When considering routing in WMSN, QoS parameters such as energy consumption, bandwidth requirement, latency and jitter need to be taken care depending on whether the data is delay or non-delay tolerant. (3) Demand for high bandwidth: Even after considering source coding and compression, video kind of data always demands for more bandwidth. (4) Energy Consumption: As transmission of multimedia data requires high transmission rates, thereby consuming more energy in the network.The inclusion of context awareness can solve the problem of energy and bandwidth consumption to a great deal. Context can be defined as the circumstance that surrounds an event and gives meaning to it. Context-aware information mainly helps to consider relevant information from the environment and transmits the same over network thereby conserving energy and bandwidth of the network. Software agents are light weight software programs that are used for performing specific tasks. Agents are of static or mobile type. Static agents reside at a particular location in the node and performs task autonomously, whereas mobile agents move through the network and performs the assigned task. In order to conserve the network lifetime of WMSN, context-aware computing along with software agent paradigm can be used together.This work proposes multi-agent based context aware multipath routing (MACMR) scheme: (1)Based on the multimedia information sensed, context is detected by using static agents.(2) Depending upon the context detected mobile agents are triggered from the event node for finding the node disjoint path between the event node and sink node. (3) Mobile agent clones triggered from the event node traverse with intermediate nodes, while traversing they carry resource information such as available bandwidth, available energy, hop count etc. and delivers it to the sink node. (4) Sink node computes the node disjoint paths based on the available resources and context. (5) Sink node sends the mobile agent with path information on the shortest path to event node. (6) Event node in turn sends the information to the sink node on the multiple paths.

1.1. Related Works

A survey on the design issues, communication architecture, algorithms and protocols developed for each layer in wireless multimedia sensor network is discussed in [1] and [2]. Several multi-path routing protocols have been proposed inthefieldof wireless sensor networks [3]. A location aware event driven multipath routing using agent technology is discussed in [4].A Context Aware Agent based Military Sensor Network (CAMSN) to form an improved infrastructure for multi-sensor image fusion has been discussed in [5] which helps in understanding the implementation of context aware model in wireless sensor networks. To discover multiple node-disjoint paths from all the sensor nodes towards a single sink nodesimultaneously is proposed in N-to-1 Multipath Routing Protocol [6]. A hybrid data transmission technique to improve reliability and security of data transmission is discussed in [7]. Multipath Multispeed Protocol (MMSPEED) as discussed in [8] is an extension of SPEED protocol which offers multi-speed transmission and establishment of more than one path to the destination to guarantee packet delivery in time.Multi-Constrained QoS Multipath Routing (MCMP) as discussed in [9] is a multipath routing protocol that uses set of partially disjoint routes to deliver packets to the sink node in order to satisfy QoS requirements in terms of reliability and delay. Energy Constrained Multipath Routing (ECMP) is explained in [10] which is an extension of the MCMP to provide energy-efficient communication.Energy-Efficient and QoS-based Multipath Routing Protocol (EQSR) is given in [11] is a multipath routing protocol that considers energy efficiency along with the quality of service constraints such as reliability and delay requirements of real-time applications. Even though many multipath routing protocols have been studied in wireless sensor networks, a very few literature exists for multimedia information routing in WMSN. Delay-Constrained High-Throughput Protocol for Multipath Transmission (DCHT) as discussed in [12] is a multipath routing approach to support high-quality video streaming in low-power wireless sensor networks. Two-phase geographic greedy forwarding (TPGF) as given in [13] is a routing algorithm that overcomes various shortcomings of scalar routing protocols. It is the first routing protocol that is addressed towards streaming of multimedia data.Forhole-bypassing, it follows two phase approaches: (1) hole-bypassing by computing the planar graph in advance without knowing the holes or boundary nodes; (2) hole-bypassing by identifying the holes or boundary node information in advance. Multi Priority Multipath selection scheme (MPMS) is discussed in [14] to choose the maximum number of paths from all found node disjoint paths for maximizing the throughput of streaming data transmission. MPMS is an extension of TGPF routing protocol.

1.2. Our Contributions

The work proposes a multi agent scheme for context aware multipath routing in WMSN. The proposed scheme considers contexts driven by event node. The agencies used in the scheme are node and sink agencies. Node agency performs context detection and interpretation based on the event detected type. Mobile agents are used for multiple path discovery and multipath routing. Our contributions to the proposed scheme are as follows: (1) Employing static agents to interpret context based on the type of data detected at the event node. (2) Context aware route discovery from event node to sink node using mobile agent initiated by the event node. (3) Initiate a mobile agent from sink node to traverse the network and collect information regarding the available resources like energy and bandwidth. (4) Computation of all the node disjoint paths based on available resources and context at sink node. (5) Initiating a mobile agent from sink node to event node with all the path information through shortest path. (6) Sensed information is sent from event node to sink node using the path information and type of context.

II. Context Aware Routing In WMSN

This section presents the network environment, proposed work, multi-agent based multipath routing and proposed algorithm.

2.1 Network Environment

Heterogeneous sensor nodes are randomly deployed in the target, which is shown in figure 1. Each sensor node is equipped with battery, Global Positioning System and software agent platform. Each sensor node hasself-organizing capability in order to communicate to the sink node/ external world. Sensor nodes deployed can sense and communicate the information to the sink node/Base Station using multi–hop communication.

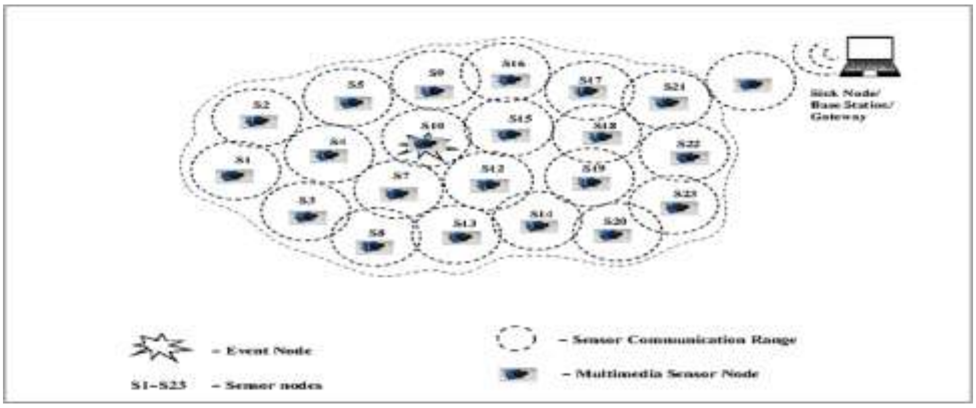

Fig. 1: Network Environment

2.2 Proposed Work

This section presents the different techniques such as context detection and classification route discovery and proposed agency.

2.2.1 Context Detectionand Classification

Different contexts used in this work are shown in figure 2. Contexts are mainly classified as emergency and non-emergency.

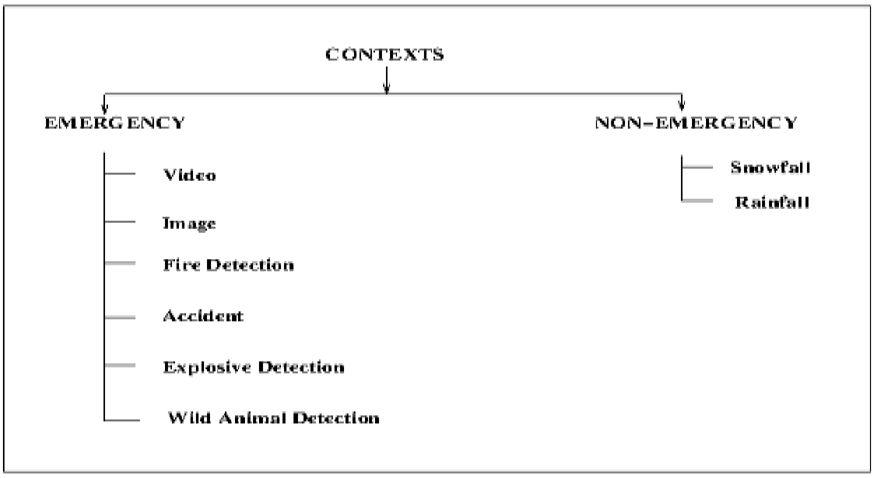

Fig. 2: Context Classification

Whenever the sensor node senses multiple parameters like humidity, temperature, rainfall, snowfall, image, video etc., then the agency situated in the event sensor node detects the context by using the multiple parameters. For example for detection of the fire, temperature and smoke should be above a threshold value, then the fire context is detected otherwise no context is detected.After detection of the event, the events are categorized into either emergency or non-emergency context. Classification of the context is performed by comparing the event information present in the knowledge base. Based on the context interpreted the number of paths are computed from event node to sink node.

2.2.2 Route Discovery

This section presents the finding of route discovery parameters such as link and route quality, energy consumption and hop distance factors that are used in the proposed scheme. Let 'C' be capacity of a channel, 'B' be the bit rate of a channel, 'Ei' be the total energy consumed for transmission of a bit in link *i*, 'SNR' be the signal to noise ratio [15]. Capacity of channel 'n' is computed by using equation (1). Quality of the link can be computed as follows.

$$\mathbf{Cn = Br\ \log_2(1 + SNR)} \qquad (1)$$

Let 'Etr' be the energy consumed for the transmission of a bit per distance'd'. 'En' can be computed by using equation (2) which is given in [15].

$$\mathbf{En = Etr \times d} \quad (2)$$

Link efficiency (Leff) can be computed by using equation (3) as given in [16].

$$\mathbf{Leff = \frac{Cn}{En}} \quad (3)$$

Route efficiency (R_{eff}) can be computed by using equation (4) by considering 'n' links on the path.

$$\mathbf{Reff = Min\ \{Leff1, Leff2, \ldots, Leffn\}} \quad (4)$$

Energy ratio in each route from event node to sink node is computed as follows:
Let Er(1) to Er(i) be the residual energy of the 'i' intermediate nodes of a route. The minimum (E_{min}) and maximum (E_{max}) of the residual energy for 'n' nodes in the route is computed by using equations (5) and (6). The route energy efficiency (Ereff) is given by equation (7).

$$\mathbf{E_{min} = Min\ \{Er(1), Er(2), \ldots, Er(n)\}} \quad (5)$$

$$\mathbf{E_{max} = Max\{Er(1), Er(2), \ldots Er(n)\}} \quad (6)$$

$$\mathbf{Ereff = \frac{Emin}{Emax}} \quad (7)$$

The distance between hop'Dh' of a path is computed by using equation (8), where Euclidean route distance from event node to sink node is 'Red' and total number of hops in a route from event node to sink node is 'Rhc'.

$$\mathbf{Dh = \frac{Red}{Rhc}} \quad (8)$$

2.2.3 Proposed Agency

Software agents are programs that execute autonomously on behalf of user or process. The proposed work consists of both static agents and mobile agents both in nodes and sink. The two main agencies considered in this work are event node agency and sink node agency. All the multimedia sensor nodes in the network have event node agency, but they get triggered when an event is detected by the node. Both event node agency and sink node agency consist of static and mobile agents to perform specific tasks.

a) Event Node Agency

Figure 3 presents event node agency, which comprised of Node Manager Agent (NMA), Event Manager Agent (EMA), Event Node Knowledge Base (ENKB) and Event Path Discovery Agent (EPDA) and Node Information Delivery Agent (NIDA).

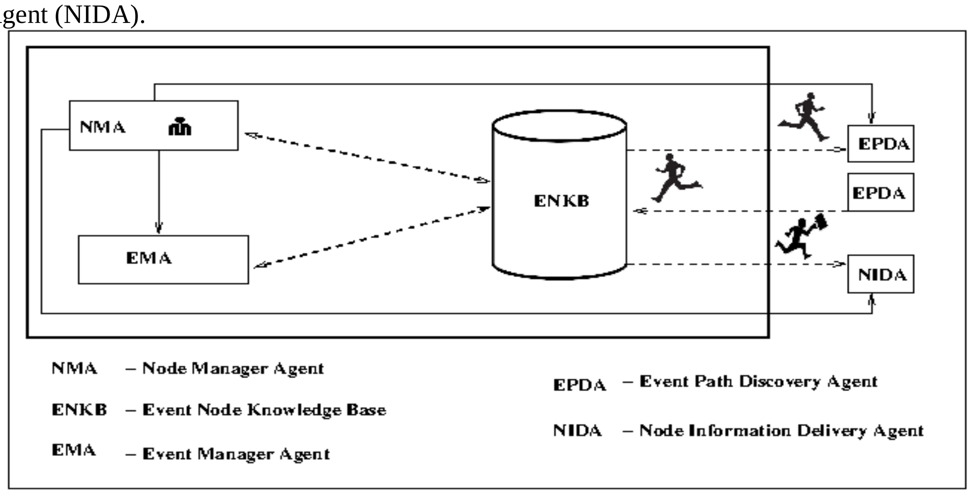

Fig.3: Event Node Agency

Node Manger Agent (NMA): It is the static agent that resides in all the sensor nodes, which is responsible for the creation of EMA, ENKB and EPDA.NMA periodically updates the context information, neighbour node information such as residual energy, location information, available bandwidth, neighbour node count and so on to ENKB.Neighbour node information is used during the path discovery. It also checks for event occurrence in the ENKB. Whenever the event is detected NMA creates the EMA. It also triggers the

EPDA for the path discovery. NMA fragments the data and the fragmented data is sent on multiple paths using Node Information Delivery Agent (NIDA) which is initiated by NMA.

Event Manager Agent (EMA): It is static agent that is responsible for the context detection and context classification. Whenever the NMA triggers the EMA, EMA gets the recently sensed information and using that information it detects the context and classify the event. Context may be emergency context or non-emergency context. It updates the context type in the ENKB. For detection of context various parameters of an event are required. Using these parameters the context is detected and updated to the sink node.

Event Path Discovery Agent (EPDA):It is the mobile agent that is triggered by NMA. Whenever the context is detected, EPDA and clones of EPDA are created. Clones of EPDA traverse in different directions towards the sink node. While traversing EPDAs carry information such as context type, traversing node weight factors and delivers it to the sink node. While traversing it also checks for path information to reach to the sink node in the visited node.If the path information is available in the intermediate node, it retraces the reverse path and comes back to the event node. NMA gets that path information and computes the multiple paths from event node to sink node.

Node Information Delivery Agent (NIDA): It is the mobile agent triggered by NMA. NMA also creates the NIDA and clones of NIDA for carrying the information in multiple paths. NIDA and clones of NIDA gets the path information and fragmented information from the ENKB and traverse to sink node on multiple path. This information is delivered to the sink node.

b) Sink Node Agency

Figure 4 presents sink node agency, which comprises ofSink Manager Agent (SMA), Path Computation Agent (PCA), Sink Path Agent (SPA) and Sink Knowledge Base (SKB).

Sink Manager Agent (SMA): It is the static agent that is responsible for the creation of PCA, SPA, and SKB. It periodically checks the SKB. Whenever SKB is updated with sensor node information such as context type and intermediate nodes information, it creates the PCA. It also generates the SPA, which carries multiple path information and delivers it to the event node.

Path Computation Agent (PCA): It is the static agent, which gets the context type and intermediate sensor nodes information and computes the node disjoint paths and shortest paths between the event nodes and sink node and updates the SKB. It also assigns the priorities/ weight for each of the path computed.

Sink Path Agent (SPA): It is the mobile agent that gets the path information and traverse in the shortest path to reach to the event node. It delivers the multiple path information computed by PCA to the event node.

Sink Knowledge Base (SKB): It is the knowledge base which can be read and updated by the entire static and mobile agents. It stores the information such as intermediate nodes information (related to path), context type, context time, node disjoint paths to reach to the event node etc. It also stores the multimedia / data information that can be accessed by users.

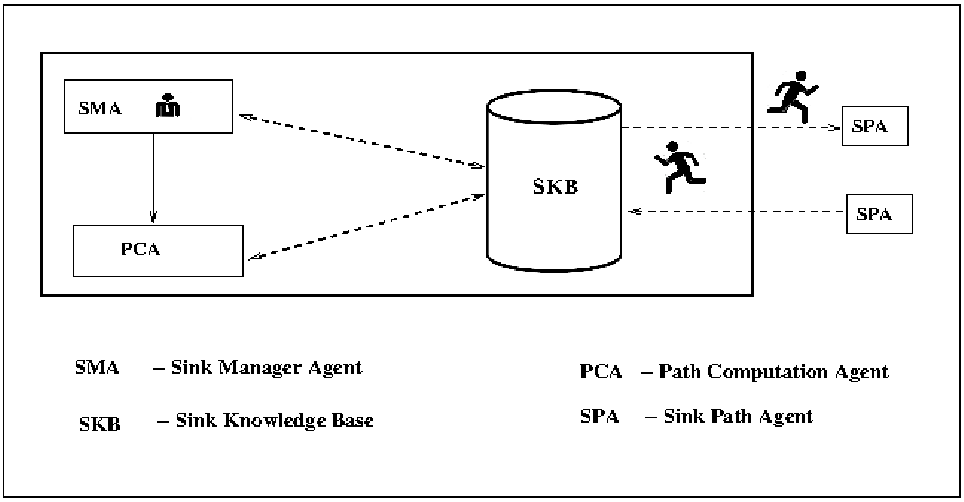

Fig.4: Sink Node Agency

2.3 Multi-Agent based Multipath Routing

Figure 5 presents the agent based multipath routing in WMSN. Whenever the event is detected, the node in which the event is detected is referred as event node. In the event node the context detection and classification is performed. Based on the context, PDA is triggered for finding the multiple paths between the event node and sink node. While traversing, PDA carries the path information from the intermediate nodes and delivers it to the sink node.

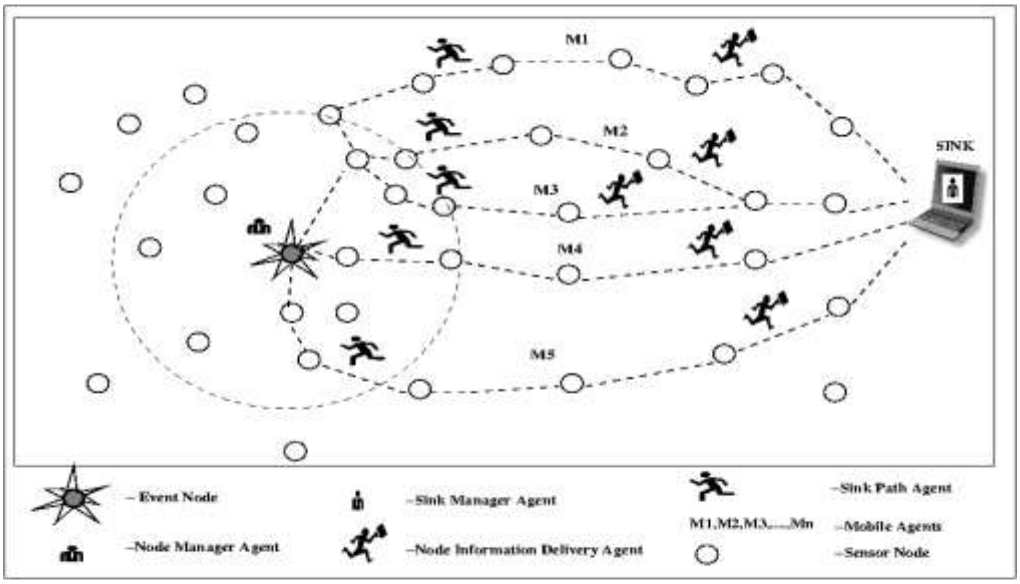

Fig. 5: Agent based Multipath Routing

PDA also checks for path information to reach the sink node in the intermediate node, if the information is available then it gets that path information and comes back to the event node and updates the ENKB. Using the path information EMA computes the multiple paths to sink node, which can be used for transmission of multimedia information on the multiple path.

2.4 Proposed Algorithm

Nomenclature:

Ei: Event information, **C**t: context type, **NMA**: Node Manager Agent, **ENKB**: Event Node Knowledgebase, **SMA**: Sink Manager Agent, **SPA**: Sink Path Agent, **E**: Available energy in node, **Eth**: Minimum energy required for transmission, **B**: Available bandwidth, **Bth**: Minimum bandwidth required for transmission, **info**: information sensed,**imageDB**: image in Database,**VF**: Extracted video frames, **ND**: Number of node disjoint paths, **MH**: Multipath High priority, **ML**: Multipath Low priority.

Algorithm 1: Context Detection

Begin
NMA gets the context information and interprets the context
while (Ei**)**
    if Ei= image **then**
        gotoImage_Detection
    else if Ei= Video **then**
        gotoEmergency_context
    else
        gotoNonEmergency_context
    end if
end while
End

BeginImage_Detection
Input: image
Compute feature vectors for images and store it in ENKB with respective images
While (image**)**
    Compute Similarity Distance for image based on feature vectors with imageDB
    Sort distance value in increasing order to perform indexing
    Retrieve image with least distance value
    Ct= Context type of concerned image from ENKB
end while
if Ct= Fire **or** Ct=Accident **or** Ct= Explosive **or** Ct= WildAnimal**then**
    gotoEmergency_context

```
else
    gotoNonEmergency_context
end if
EndImage_Detection

BeginEmergency_context
NMA updates ENKB with context information
SMA initiates PCA to compute Multipath with Highpriority
EndEmergency_context

BeginNonEmergency_context
NMA updates ENKB with context information
SMA initiates PCA to compute Multipath with Lowpriority
EndNonEmergency_context
```

Algorithm 2: Multipath Routing with High priority

```
Begin
Input: info
if info=video then
    VF= Extract frames of Video
end if
for i=1 To N do
    while (E>Eth and B>Bth)
        PCA computes ND
        MH=NDi
    end while
end for
Output: MH
SMA initiates SPA with MH
End
```

Algorithm 3: Multipath Routing with Low priority

```
Begin
Input: info
for i=1 To N do
    PCA computes ND
    ML= NDi
end for
Output: ML
SMA initiates SPA with ML
End
```

III. Simulation Procedure

This section discusses about the simulation inputs as given in Table 1 and the performance parameters considered for analyzing the scheme. The proposed scheme is compared with that of MPMPS [14].

Table 1: Simulation inputs

Parameter	Notation	Value
Length	L	5000m
Breadth	B	5000m
Number of nodes	N	200
Number of Transmitting Nodes	Nt	40-200
Propagation constant	β	2.5
Transmission range	R	300m-500m
Sensing Range	Sr	5-15 meters
Sensed Video Generation Rate	Vc	72 Kbps
Bandwidth for every Hop	Bh	10 Kbps
Initial energy of each sensor node	E	1 KJoules
Number of packets per seconds	Tpkts	256 Per Second
Size of sensed data at each node	Sd	8 Kbytes
Size of the processing code	Sp	5 Kbytes

Simulation procedure involves following steps:
1. Generate sensor network environment.
2. Event node sends the partial topology information to sink node.
3. Apply the proposed scheme.
4. Compute performance parameters of the system.

The following performance parameters are assessed in the proposed scheme:
Packet delivery ratio: It is a ratio of total number of packets received to total number of packets sent.
Energy consumption: It is the total energy consumed for the path discovery, path setup and sending data from event node to sink node. It is expressed in terms of milli Joules.
Latency: It is the total time taken for the data to be transmitted from event node to sink node. It is expressed in terms of milliseconds.
Number of paths: It is the total number of node disjoint paths between the event node and the sink node.

IV. Result Analysis

This section presents the results obtained during simulation.We compare results of proposed work with an existing Multi-priority Multi-path Selection (MPMPS) scheme for WMSN.

4.1 Packet Delivery Ratio based on Communication Range

Figure 6 presents packet delivery ratio (PDR) for given numberof nodes involved in transmission based on the communicationrange. The PDR increases with increase in communication range and decreases with increase in number of transmitting nodes.

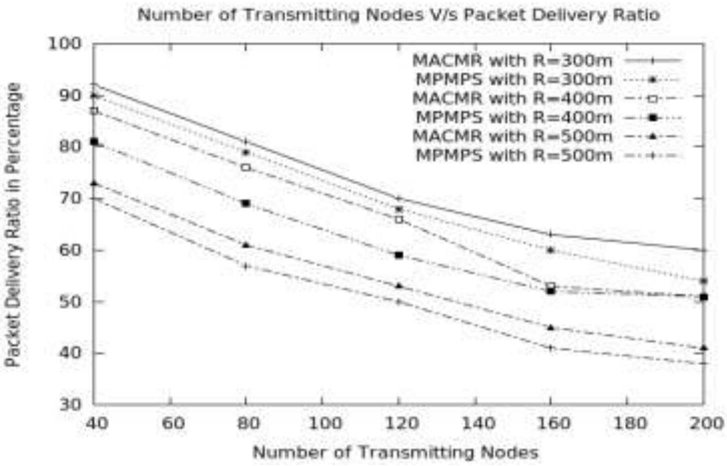

Fig. 6: Number of Transmitting Nodesvs.Packet Delivery Ratioin Percentage

4.2 Latency for Non-Emergency Context based on Communication Range

Figure7 describes the latency for the given number of transmitting nodes and the communication range based on the non-emergency context type. As the number oftransmitting nodes and the communication range increase,time required to gather and compute the multiple disjoint paths will also increase.

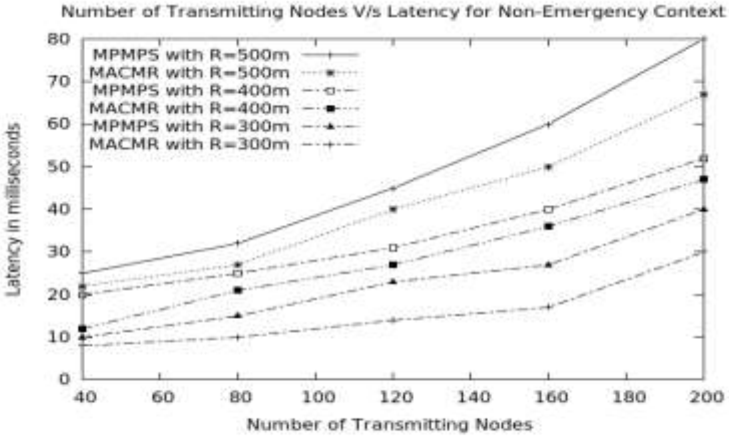

Fig.7: Number of Transmitting Nodesvs.Latencyfor Non-Emergency Context in milliseconds

4.3 Latency for Emergency Context based on Communication Range

Figure 8 describes the latency for the given number of transmitting nodes and the communication range based on the emergency context type.It can be noted that, as routes with high resources and priority are assigned to the emergency context type data, latency is minimized when compared to latency of non-emergency context type. As the number of transmitting nodes and the communication range increase, time required to gather and compute the multiple disjoint paths will also increase.

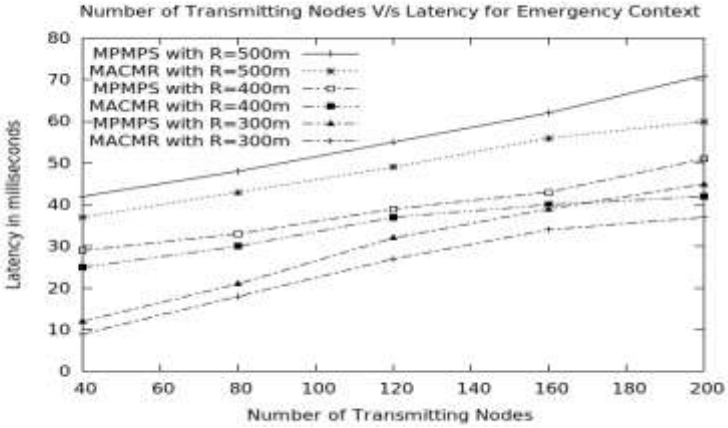

Fig.8: Number of Transmitting Nodes vs. Latency for Emergency Context in milliseconds

4.4 Energy Consumption based on Number of paths and Number of Transmitting Nodes

Figure9 explains the energy consumption for the given number of transmitting nodes and number of paths. With increase in the number of nodes and number of paths, theenergy consumption increases in both MPMPS and MACMR.

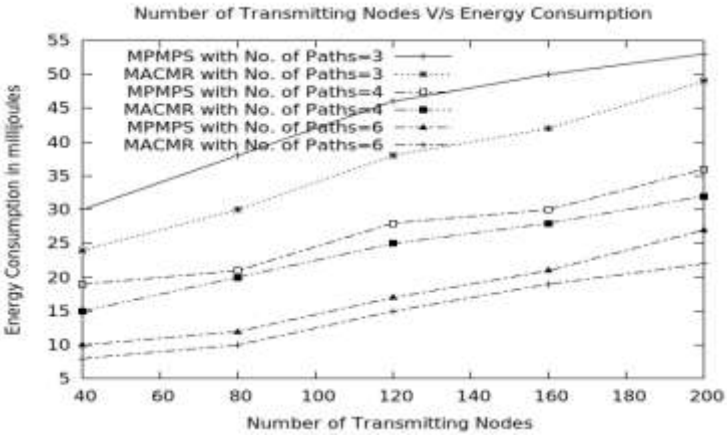

Fig.9: Number of Transmitting Nodes vs. Energy Consumption in millijoules

4.5 Number of Paths generated based on Communication Range

Figure10 shows the number of available node disjoint paths in MACMR with given number of nodes in the network and thecommunication range. The disjoint paths increase withincrease in number of nodes and transmission range. Such a result is obtained as mobile agents move in different directions to obtain multiple paths based on the contexts.

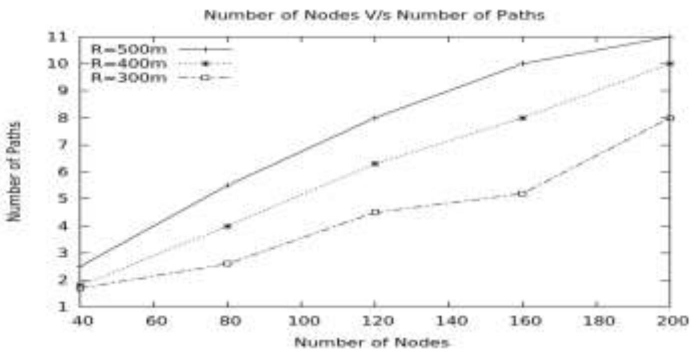

Fig.10: Number of Nodes vs. Number of Paths

V. Conclusion

A multi-agent based context aware multipath routing scheme (MACMR) which is event driven is proposed in this paper. Once an event is detected by a sensor node, the software agents in the node gets activated and perform route discovery through the clones of mobile agents assigned by the manager agent in the event node. Sink node once it receives the paths from the event node to the sink node, the manager agent in sink node initiates path computing agent to compute node disjoint paths to the sink node based on the resource information available. Once the path gets computed mobile agents are triggered by the manager node in sink to carry the path information to the event node. Event node fragments the data and sends the information based on the type of context to the sink node through clones of mobile agents initiated by manager of event node. The proposed scheme performed better with respect to performance parameters like packet deliver ratio, energy consumption and latency, when compared with MPMPS,as software agent technology is considered along with context awareness to send multimedia information like videos and images in WMSN.

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