CHAPTER 4

ADAPTIVE ENERGY EFFICIENT AND RELIABLE GOSSIP ROUTING PROTOCOL

We propose Adaptive Energy Efficient and Reliable Gossip Routing Protocol (AEERG) to achieve both energy efficiency and reliability in wireless ad hoc networks. Functional mechanism of AEERG routing protocol is as follows:

Let us assume that every node in the ad hoc network chooses an equally distributed random time interval, known as gossip interval for sleep-active cycle. When the time is up, the node will immediately choose another random interval independently. To make it possible, we assume the feasible maximum gossip interval is much smaller than the lifetime of the network.

1) Each node independently generates a random time interval and chooses either going to sleep with probability \( p \) or staying awake with probability \( 1 - p \) for the interval.

2) Every sleeping node wakes up at the end of its interval.

3) Every node repeats the above process for every random interval independently.

In our proposed protocol, network is deployed with fixed number of nodes within a small area. Initially, all the nodes are set in sleep mode with probability \( p \) and active mode with probability \( (1-p) \). Among the active nodes,
communication takes place. All of them maintain a buffer which gives information on active neighbors’. The node initially starts its communication to neighbouring node with a buffer value as one. Buffer value of ‘1’ represents number of active neighbors is one for that active node. Even though we have only one active neighbour node for a communicating node, there may be many nodes in an active mode due to high density of network. This enables the network with full connectivity even in the presence of sleep nodes.

Each buffer named B holds the list of current neighbor members and the distance between themselves to actual communicating node. At each node, this gives the details of neighbor node members which are kept in active state.

The format of table in buffer is as follows:

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Source Node ID</th>
<th>Neighbor node ID</th>
<th>Distance between source and neighbor node</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The rest of the nodes in the network will be in either sleep state with probability $p$ or active state with probability $1-p$. The higher value of $B$ represents more number of active neighbors. This situation consumes more power, since node need to send packets to all active nodes. Transmission to all active nodes results with more energy consumption. Let a source node $X$ needs to broadcast a data packet. $X$ looks up its neighbor list for distance between itself and its neighbors listed in B. Buffer B updates its information based on AODV route establishment procedure. $X$ then calculates the amount of power needed to send the packet to that neighbor. Initially, every node initializes B to one. This means initially, a node broadcasts data packets only to its closest neighbor, thus requiring the least power. After sending data
packet, node X waits for a feedback from destination. While receiving packets at the destination, the packet delivery ratio D is calculated and it will be sent as a feedback to the source. The routing protocol used for this is AODV. Packet delivery ratio is the ratio of number of packets received by the destination node to the number of packets transmitted by the source.

Generally, we assume that there is a uniform node density, in particular that no parts of the network are sparse. For simplicity, we assume that all nodes of the ad hoc network have the same broadcast range: one hop. This will be our unit of measurement. A one hop distance is a covering of the Euclidean plane with regular hexagons, or cells-as shown in Figure 4.1

![Figure 4.1 Node with its broadcast range](Image)

Huang et al (2005) have proposed that to maximize the one hop distance, the cell radius should be increased by improving antenna radiation pattern. So, only one cell will get the message within the cluster. In this way, gossiping reduces energy. Our approach in general will be to have at least one node from each cell to be active and propagate the message (a gossip node), resulting in cell-to-cell propagation (as we see in Figure 4.2, some cells can be silent).
Figure 4.2 Minimum connected full network connectivity nodes

If the network is not having nodes like hexagonal cells coverage, it would have been occupied by randomly placed nodes (Andrew Tanenbaum 2003). But each wireless node has three regions around it as shown in the Figure 4.3. So, in our proposed work, the nodes can communicate to neighbor active nodes through the antenna within the transmission region. So, the interference can be reduced. If the network has sparsely located nodes, the coverage area of antenna can be improved so that the communication is feasible within the transmission region.

Figure 4.3 Ranges for transmission, detection and interference of signals
- **Transmission range**: Within a certain radius of the sender transmission is possible. A receiver receives the signals with an error rate low enough to ensure accurate communication and can also act as sender.

- **Detection range**: Within a second radius, detection of the transmission is possible. The transmitted power is large enough to differ from background noise. However, the error rate is too high to establish communication.

- **Interference range**: Within a third even larger radius, the sender may interfere with other transmission by adding to the background noise. A receiver will not be able to detect the signals, but the signals may disturb other signals.

### 4.1 FLOW CHART OF AEERG ROUTING PROTOCOL

The flow chart for our proposed protocol is shown in Figure 4.4.

The proposed protocol depends on adaptive technique. So, the computed packet delivery ratio is compared with reliability threshold at the source node. Based on comparison, if less value is obtained, in adaptive technique, RF signal triggers the node from sleep mode to active mode. Once reliability is achieved, nodes which are triggered into active mode are again driven into sleep mode. So, we achieved energy conservation with reliability.
Start

Sleep probability = \( P(s) = p \)
Awake probability = \( P(a) = 1-p \)

Set counter \( B \) - indicates the no of active neighbors. Initialize \( B \) value to 1. i.e. \( B = 1 \)

\[ B = B + \alpha \]

\[ B = B - \alpha \]

At \( Y \) set counter \( P \) to represent the no of paths and set timer \( T \) to calculate the Arrival Time (AT)

Let No of paths = 0
(Counter value \( P = 0 \))

Set delay period (DP)

\[ \text{Figure 4.4 Continued} \]
Figure 4.4 Continued
Here,

RT = Reliability threshold

D = Delivery ratio = No of packets received / No of packets sent

AT = Arrival Time = the time at which message received

SP = Shortest Path

DP = Delay Period = 100 μs

B = A counter which represents the Number of active neighbors

P = A counter which represents the Number of Paths

α = (k/100)* total no of nodes

Figure 4.4 Flow chart of AEERG routing protocol
AODV routing protocol establishes the path through route request (RREQ) packet. After getting route reply (RREP) packet, the path will be established. Active nodes hear beacon signal at the beginning of active mode in adhoc network. If beacon signal is not heard, the node (X) generates and transmits its own beacon signal to a neighbour node (X1). The beacon signal has time stamp with ATIM window. ATIM window is used to announce the neighbour active mode (Single hop ATIM window) about packet transfer mechanism. Through ATIM window, the neighbour node (X1) continued to be in active mode for receiving packets from previous node (X). So, the nodes are in active mode till the packet transfer takes place. Through that same path, value of packet delivery ratio D is sent to the source node. If X gets a feedback D for the data packet below a reliability threshold (RT), X increases the value of B by an adaptive procedure. The number of active nodes is increased by trigger signal. This assures the increased delivery ratio. When D becomes greater than or equal to RT, the value of B is decreased adaptively, by decreasing the number of forwarding nodes. So, there is a decrease in probability of active nodes. This process continues for every beacon period interval. While receiving a feedback, after the computation of D value, X starts to decrease the value of B (after a certain number of acknowledged data packets) to a small value which may equal to one. This process is repeated for every beacon interval.

Initially, the nodes are deployed with a sleep - awake schedule mechanism in a network. During sleep state of the node, the battery level is not utilized for any purpose. The proposed protocols are comparing the PDR with threshold value. If it is less, by adaptive manner, sleep state nodes are triggered into active mode. Adaptive mechanism needs trigger signals from which the awakening mechanism is established. Once the node has reached the desired Packer Delivery Ratio threshold value, the triggered node will be
driven to sleep mode again. In this manner, the proposed protocol efficiently utilizes the battery energy level.

4.2 AEERG ROUTING PROTOCOL

1) Let sleep probability \( P(s) = p \) and awake probability \( A(s) = 1 - p \).

2) Let initial value of \( B \rightarrow 1 \).

3) Source \( X \) broadcasts data packets to Destination \( Y \).

4) At \( Y \), calculate packet delivery ratio \( D \),

\[
D = \frac{\text{Number of packets successively received}}{\text{Total Number of packets sent}}
\]

5) \( Y \) sends \( D \) as a feedback to \( X \).

6) At \( X \), If \( D < RT \) then,

6.1. \( B = B + \delta \), where \( \delta \) is the fraction scale factor (approximately 0.05% of total nodes).

6.2. Repeat from 3.

7) Else. If \( D \geq RT \), then,

7.1. If \( B > 1 \), then,

7.1.1. \( B = B - \delta \)

7.1.2. Repeat from step 3.

7.2. End If

8) End If

9) Repeat from step 3.
To summarize, AEERG routing protocol has the following salient features:

1) Unlike existing routing schemes, AEERG routing protocol is neither single-path nor multi-path; rather each node exploits the multiplicity of paths based on its observed loss conditions.

2) Under AEERG routing protocol, only for low packet delivery ratios, a node uses high-powered transmissions to reach farther neighbors. For high packet delivery ratios, a node adapts low-powered transmissions.

Thus, AEERG routing protocol sensibly consumes power based on receiver distance, which maximizes the lifetime of the network and minimizes power consumed per successfully delivered data.

3) AEERG routing protocol aggressively probes for possible routes to deliver data packets, thus reacting quickly within unreliable areas of the network.

In non uniform distributed network, let us assume the nodes are distributed as shown in the Figure 4.5. Based on three propagation regions as explained earlier, the data packet is transmitted and received within the transmission region. The nearby node receives the data packet by one hop behavior. From that node, by gossip, to nearby another active node, the data is transmitted.
Figure 4.5 Illustration of triggered node

After sending data packet, source node waits for a feedback from destination. Arrival of feedback time is noted down as T1. If source hears a feedback D for the data packet below a reliability threshold RT, source increases the number of neighbors. For this, the other paths through which we received the feedback are also taken into consideration. Arrival Time of that corresponding path is noted down as T2, T3 etc. The secondary path nodes based on arrival time are triggered from sleep modes into active modes and so the probability of active nodes varies adaptively. Increase of active nodes assures that increased number of successfully received packets in terms of by large percentage of packet delivery ratio. When D becomes greater than or equal to RT, the number of neighbors is decreased adaptively. To decrease the number of forwarding nodes active modes are triggered into sleep modes and there by decrease the probability of active nodes. In that process, induced active nodes in the secondary path are once again triggered to sleep mode. This results into decreasing the value of B. This process continues and repeats for every beacon signal until either source node hears a feedback for the packet, which equals the reliability threshold value RT or the number of neighbors reaches a minimum value of one. Beacon signal is used to change
the mode of nodes from sleep to active or vice versa. So the value of B is adaptively changed.

In this protocol, nodes are woken up to send the packets to its destination rather than getting active periodically to verify whether there is pending traffic. The schematic representation of the switch, so-called RAS Chiasserini et al (2001) (Remote Activated Switch), is shown in Figure 4.6.

This RAS is placed as part of the IEEE 802.11 physical layer. In our proposed work, the IEEE 802.11 low power mode is used. Whenever a node becomes idle, it enters into a sleep state, i.e., the standard receiver/transmitter is turned off as well as part of the device electronics. Waking-up signals are received and demodulated by the RAS. Then the signal information is passed to the logic circuit that detects the sequence. Logic circuit performs the comparison operation. As step 1 procedure, RAS check the power of node. In step 2, if the power is less than half of its initial energy, information has been sent. Then in step 3, as a passive device, from received RF signal power is consumed. In step 4, as power is sufficient in the node, from battery, power is consumed. In step 4, if the sequence is matched, the device switch for transmitter/receiver operation is switched on. In step 5, if the node is triggered to active mode, power for the operation will be taken from battery.

If the received sequence matches the device’s sequence, it turns on the standard receiver of that node. Notice that the RAS receiver may be either totally passive (e.g., an amplitude demodulator) or supplied by the battery source through connection 1.
The major objective as proposed in this protocol is to achieve energy efficiency by placing more number of nodes in a sleep mode and also to achieve reliability. The sleep nodes in the path of the packet transmissions are changed to active state by a triggering signal which consumes power from the RF signal itself. So, packets are reaching to the destination without any loss with energy conservation. This enables achievement of reliability and energy conservation compared to existing protocols. The mathematical approach has been explained in the next sub-division.

4.3 MATHEMATICAL MODEL ANALYSIS FOR AEERG PROTOCOL

Mathematical model interrelating PDR with energy has been developed and the model is given below.

Let the variables be defined as follows in AEERG protocol:

\( S_n \) - Source node
$D_n$ - Destination node

$D$ - Distance between $D_n$ and $S_n$

$k$ - Coefficient of attenuation ($2 \leq k \leq 4$)

$\xi_i$ - Energy requirement for a single packet to be forwarded from a single node

$\xi_{opt}$ - Optimal transmission energy to transmit a single packet from one node to its intermediate node

$\xi_{total}$ - Total optimal energy spent in a node to transmit all packets between $S_n$ and $D_n$

$D_{i,i+1}$ - Distance between consecutive $(i , i+1)$ nodes

$H$ - Represents the total number of hops between $S_n$ and $D_n$

$H - 1$ - Number of forwarding nodes between $S_n$ and $D_n$

$a$ - Proportionality constant

$M$ - Number of active nodes in the routing path

$M_1$ - Number of nodes sufficient to have successful transmission of a packet through a shortest path between $S_n$ and $D_n$ in AEERG

$p_{er}$ - Packet error rate

$\delta$ - Fraction of nodes which undergo transition between sleep – awake states

$(T_{SD} , t)$ - Distribution of traffic (load) between each pair of $S_n \rightarrow D_n$ defined in a matrix of gravity
\( \beta \) - Total load between \( Sn \) and \( Dn \) (received data in bytes/sec)

\( \rho \) – Transmitted data in bytes/sec

\( RT \) - Reliability Threshold

\( L \) - Number of paths between \( Sn \) and \( Dn \)

\( P_s \) - Packet size

Let us assume that communication has been established between \( Sn \) and \( Dn \). Path between \( Sn \) and \( Dn \) is named as \((i \rightarrow j)\).

The transmitted signal suffers attenuation due to the wireless medium characteristics. Attenuation of the medium is proportional to \( D^k \), where \( D \) is the distance between \( Sn \) and \( Dn \). Log Distance Path Loss Model (Jochen Schiller 2003) is used for this work within radio coverage range. We assume constant-power scenario.

Optimal transmission energy to transmit a single packet from one node to its intermediate node \( \xi_{opt} \) is proportional to \( D^k \) and it is given by (Woesner et al 1998):

\[
\xi_{opt}(D) = a.D^k
\]  

(4.1)

‘a’ is the proportionality constant.

Since links are considered as error-free, minimum hop paths are most energy-efficient for the constant-power case.

Forwarding distance between forwarding node and next-hop node determines path loss. Reducing the maximum forwarding distance by selecting a good receptive next node is an effective procedure to reduce the
path loss. Reducing the forwarding distance in the constant-power formulation as in Equation 1, reduces the $\xi_{opt}$. It is very easy to obtain the desired $\xi_{opt}$ by placing an intermediate node along the straight line between two adjacent nodes (breaking up a link of distance $D$ into two shorter links of distance $D_1$ and $D_2$ such that $D_1 + D_2 = D$).

Consider a communication between $S_n$ and $D_n$ separated by a distance $D$ as shown in Figure 1. Energy-throughput relationship is analyzed for a path with multiple short hops.

![Illustration of multihops](image)

**Figure 4.7 Illustration of multihops**

The intermediate nodes can be indexed as $i$ with $i = \{1, 2, 3, 4...H-1\}$. Node $i$ refers to the $(i)^{th}$ intermediate node in the forwarding path. In this case, the total optimal energy spent in a node to simply transmit a packet once (without considering whether or not the packet was reliably received) from the sender to the receiver over the (H-1) forwarding nodes $\xi_{total}$ is given by:

$$\xi_{total} = \sum_{i=1}^{H-1} g_{i,i+1} \xi_{opt}$$ (4.2)

Or, by using Equation 4.1

$$\xi_{total} = \sum_{i=1}^{H-1} a_i D_{i,i+1}^k$$ (4.3)
The above $\xi_{\text{total}}$ is calculated for proactive and reactive type routing protocols.

4.3.1 Energy Estimation for the AEERG protocol

In AEERG protocol, all the intermediate nodes between $S_n$ and $D_n$ are not in active mode. The probability $(1-p)$ will determine the number of active nodes in the routing path and it is denoted by the variable $M$. $\xi_{\text{total--EN--EFF}}$ is the energy requirement associated with the choice of $M$ nodes for successful communication. It is given by

$$\xi_{\text{total--EN--EFF}} = \sum_{i=1}^{\lfloor M \rfloor} a_D^i \tag{4.4}$$

From this it is clear $\xi_{\text{total--EN--EFF}} < \xi_{\text{total}}$. In AEERG protocol, $M$ numbers of active nodes are used for communication. But all active nodes are not used in the link $i \rightarrow j$ for communication. We can establish the communication by transmitting packet through nearby intermediate nodes and it is termed as variable $M_1$. Nearby node’s information is available in buffer $B$ which is present in each node. So, energy consumption is reduced. This can be explained as follows.

In order to ensure the data transfer between $S_n$ and $D_n$, by means of RF signal, the nodes are adaptively triggered into active mode/sleep mode. Let $\delta$ be the fraction of nodes which undergo transition between sleep – awake states. So, $M_1 \pm \delta$ numbers of active nodes are necessary. So, the energy consumption can be calculated as

$$\xi_{\text{total--AEERG}} = \sum_{i=1}^{\lfloor M_1 \pm \delta \rfloor} \alpha D_i^k \tag{4.5}$$

The above equation shows that there is a reduction in energy consumption since the adaptive technique reduces the number of active nodes
for communication. From this, it is concluded that \( \xi_{\text{total EN EFF}} < \xi_{\text{total AEERG}} \) by comparing equation 4.5 with equation 4.4.

We know that \( \xi_i \) is the energy requirement by a node to forward a single packet to its neighbours. So from this, we can calculate the number of packets received in destination node and it is given by

\[
N_p = \frac{\xi_{\text{total AEERG}}}{\xi_i} 
\]  \hspace{1cm} (4.6)

### 4.3.2 Computation of Packet Delivery Ratio for AEERG Protocol

By properly choosing next intermediate receiving node, we have to reduce the number of hops occurring in a route. Since we have considered a non-linear network of randomly distributed nodes, it is difficult to determine the exact value of distance between a source and next-hop node. Therefore, this distance can be considered as a random variable and its mean value can be determined.

All wireless nodes use the same power to transmit signals. Simple gravity model estimates the entire traffic \( T_{SD} \) (in bits/sec) between \( S_n \) and \( D_n \) (Radhika Ranjan Roy 2011). In this case, total load \( \beta \) between \( S_n \) and \( D_n \) is given by

\[
\beta = T_{SD}(t) \hspace{1cm} (4.7)
\]

Transmission time varies from link to link and thus its exact value cannot be determined. Therefore, we have considered it as a random variable and estimated its mean value.
The load $\beta$ (in bytes/sec) is measured and it is used to calculate PDR at the destination node $D_n$. Since the link is assumed error free, maximum of $\beta$ value is expected. PDR is computed as below.

$$PDR = \frac{\beta}{\rho}$$  \hspace{1cm} (4.8)

The PDR value is sent as feedback factor to $S_n$. At node $S_n$, PDR is compared with Reliability Threshold $RT$.

Based on the arrival time of PDR, node $S_n$ will compute the Round Trip Time (RTT). $T_{rec}$ is the time at which PDR has been received and $T_{gen}$ is the time at which packets are generated at $S_n$.

$$RTT = T_{rec} - T_{gen}$$  \hspace{1cm} (4.9)

If RTT is very small, then node $S_n$ will decide that path is the shortest path. The time duration is noted as $T_{sp1}$ in which PDR has arrived to node $S_n$. Similarly, next short paths timings are noted down as $T_{sp2}$, $T_{sp3}$, etc…

### 4.3.3 Interrelation of Energy consumption with Reliability in AEERG protocol

The optimized $RT$ value is 0.5. The value $RT$ has been preset in every node of the deployed network. At node $S_n$, PDR is compared with Reliability Threshold ($RT$). If PDR is lesser than $RT$, sleep nodes are triggered into active mode within short path.

So, the number of nodes within the shortest path is increasing which is termed as $M1 \pm \delta$. The value $\delta$ is the fractional number of nodes which are triggered into active mode. So, the load $\beta$ will increase between
Sn → Dn. This in turn, increases the value of PDR. A high value of PDR means that receiver has received maximum number of packets from transmitter. Throughput depends upon the number of packets received. So, good throughput is achieved in AEERG which results into reliable communication.

Once the desired value of $RT$ is obtained, triggered nodes are again driven to sleep state. Energy consumption is computed by equation 4.5 and it is given by

$$\xi_{\text{total-AEERG}} = \sum_{i=1}^{i=M} aD_i^k$$

Number of packets received

$$N_p = \frac{(PDR * \beta)}{P_s}$$ \hspace{1cm} (4.10)

$P_s$ - denotes the packet size

Based on equation 4.6 and equation 4.10, we can write the interrelation between energy consumption and load as

$$\frac{\xi_{\text{total-AEERG}}}{\xi_l} = \frac{\beta}{P_s}$$ \hspace{1cm} (4.11)

So from above equation, we can write $\beta = (\frac{\xi_{\text{total-AEERG}}}{\xi_l})*P_s$

Therefore,

$$PDR = \frac{\beta}{\rho} = (\frac{\xi_{\text{total-AEERG}}}{\rho*\xi_l})*P_s$$ \hspace{1cm} (4.12)

The Equation 4.12 gives interrelation between PDR and Energy consumption.
Based on the mathematical model, the following values are computed:

To estimate energy consumption, we have taken \( D \) as 10 m and \( a \) value is 0.01 and the value of \( k \) is 2.

We assume dense node deployment for our work.

Number of nodes taken in network = 22 nodes

Sleep probability = 0.4.

Hence, number of sleep mode nodes = 9.

And number of active mode nodes = 13.

Among 13 active nodes, 10 are taken for communication between source and destination.

So, we can estimate throughput which ensures that the packets are received by the receiver.

These results in reduced energy consumption since lesser number of intermediate nodes are used for communication.

Transmitted data = 49,200 bytes/sec

Load = 48,200 bytes/sec (from equation 4.7).

PDR = 0.979 (from equation 4.8).

Since CBR packets size - 512 bytes is chosen. We can estimate

Number of received packets = 92 (from equation 4.10)
10 active intermediate nodes are taken from source to destination each separated with a distance of 10m.

The mobility speed of node is 20m/sec. Energy required to forward a single packet from a node is calculated as 0.053 joules. Because of the mobility, the packets pass through on average of 5 intermediate nodes from the source to destination.

Energy consumption = 5 joules (from equation 4.5)

Number of received packets = 94 (from equation 4.6)

<table>
<thead>
<tr>
<th>S.No</th>
<th>Calculated</th>
<th>Simulated</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PDR= 0.979</td>
<td>PDR=0.982</td>
</tr>
<tr>
<td>2</td>
<td>Energy consumption=5 Joules</td>
<td>Energy consumption=5.38 Joules</td>
</tr>
</tbody>
</table>

This comparison shows that simulation values are very close to theoretical value.

In all active-sleep scheduled protocols, there is a trade off relationship between energy conservation and throughput. But in our proposed AEERG protocol, by means of adaptive technique, sleep nodes are triggered into active mode in the shortest path of communication. So, with reduced energy consumption, reasonably high throughput can be achieved.

4.4 TCP AND CBR TRAFFIC – IMPACT ON AEERG ROUTING PROTOCOL

Information regarding individual node behavior can be used for identifying selfish behavior in the network. Also, an approximation of arriving and departing traffic load, at each node, is important in the context of
quality of service, load balancing, and congestion control. Furthermore, the network topology picture can provide valuable information for network management in detecting preferred routes and its bottlenecks, discovering network partitioning, and in detecting faults. In proposed protocol, nodes are deployed in a high-traffic environment, with multiple connections. In order to reduce the overload, rate of packet generations has been reduced. The speed of transmission can be increased. These can be set as parameters in NS-2 simulator. For our experiments, 4packets/sec and the speed as 20m/sec has been set as parameters. Comparisons with TCP and UDP flows for the network are simulated using ns-2 simulator and the performance metrics analyzed.

Applications of this work:

1. Military communication: There may be a number of authenticated and secret communications between different sections of Armed forces. All communications are need not be a mesh network. Only selective nodes may receive communication in order to maintain secrecy. But all the communication may be known to head of Military who may be central node to act as administrative one. Through that shortest path, all emergency communication can be made

   a. Another example is battlefield. Assuming, a number of battalion tanks with a receiver in different locations with an unpredictable movement. The commander of battalion may be a central administrative node. He may get feedback from the front end of the battle field and the size of the real battle field will be large in size. So, direct communication from the commander to specific front end node is not possible. As a result, information about
the front end node will be relayed to other tanks in the battle field. At the same time, these other tanks in the battalion may be communicating themselves using audio signals; and urgent messages are being relayed between the tanks as illustrated in the figure. The various communications are represented as arrows in the Figure 4.8.

![Figure 4.8 Illustration of battle field’s communication](image)

All these applications need to be supported by ad hoc network without replenishing energy within the battlefield and with a good Quality of Service between them.

2. **Video Gaming**

Video gaming is expanding rapidly and the latest technology development is multiplayer in a single game. This developments leads to allow players to play a multiplayer game with hand held device with wireless connectivity over an ad hoc network. This application requires wide bandwidth with a high QoS. Also, critical control information should be relayed quickly and accurately for a single game to be played.
3. Business network:

For business collaborative work, gathering of data must be more important in outside office environments than inside. So, it is in the hands of people to have meeting among them in an adhoc manner and exchange the required information. Any day-to-day activity applications such as electronic email and file transfer can be considered to be easily deployable within an adhoc network environment. Web services are also possible if anyone of the node is acting like a gateway to outside world.