CHAPTER 4

ANT COLONY OPTIMIZATION IN COOPERATIVE NETWORKS

4.1 INTRODUCTION

The proposed method presents a new architecture based on the principle of cooperation between the networks in which MIMO technology is virtually introduced to transmit information using Ant Colony Optimization. It is a new natural computation method that mimics the behaviours of ant colony. It is a very good combination optimization method. To extend the ant colony optimization, some continuous Ant Colony Optimizations have been proposed. To improve the performance, the principles of evolutionary algorithm and artificial immune algorithm have been combined with the typical continuous Ant Colony Optimization, and one new Immunized Ant Colony Optimization is proposed here. Implementing network coding on commercially available mobile devices, the performance is presented in terms of throughput, delay and energy consumption. To improve the performance within the cooperative cluster even more, network coding seems to be a promising technology as it decreases the number of packets to be interchanged among cooperative mobile devices leading to a decreased packet delay. The energy saved by fewer packet transmissions is confronted with the energy needed to carry out the network coding and related overhead.
4.2 MAX-FLOW MIN-CUT THEOREM

The MIMO co-operative model uses the principle of the co-operation between the terminals, in order to exploit spatial diversity in an Ad hoc network and to optimize the use of the various nodes while drawing aside the MIMO system virtually to have a good improvement of QOS. Ant Colony Optimization (ACO) is a new natural computation algorithm that mimics the behaviour of ants in a colony. The original intention of ACO is to solve the complicated combination optimization problems, such as TSP, so the traditional ACO is a very good combination optimization method. Its basic biologic principle is briefly introduced as follows. As one kind of social insect, the behaviour of ant is very simple, but the ant colony can represent very complicated behaviour, and can complete very complicated task. Scientists have noticed this phenomenon for a long time.

From a lot of research, they found that the information is delivered among ant colony by one kind of hormone. Through this kind of information exchange, the ant can cooperate and complete very complicated task. As the ant moves, the hormone is released on its path. The follow ants can perceive this hormone and recognize its density, and have a larger probability to move along the path that has the greater hormone density. So, this is a kind of positive feedback information. The more number of ants that move along a road, the more is the probability of follow ants to move along the same road. Based on the above principles, the ant colony optimization can solve very complicated combination optimization problems. For cooperative wireless networks the network coding seems a viable solution to decrease the traffic within the short range cluster and with that to decrease the delay and the energy consumed. Packet loss is very common in wireless networks. In what packets should the relay transmit, in order for native packets to be obtained by intended receivers. The type of network coding has recently received a lot of
practical interest for its ease of implementation and the importance of multicast communication. The terminology of network coding, a non encoded original packet is referred to as a native packet. The messages enabled the information flow to reach the maximum capacity as given by the max-flow min-cut theorem for network information flow. The basic idea of network coding can be illustrated by using the multicast butterfly example in Figure 4.1.

In this example all edges have a capacity of one bit per unit time. By the max-flow min-cut theorem, it is seen that the max-flow from the source $s$ to the sinks $t_1$ and $t_2$ equals two. Thus that the maximum number of bits simultaneously delivered at each of the sinks should be equal to two. Clearly, by inspection of the graph this cannot be achieved without some form of coding, as the middle node is limited to one outgoing bit per time unit. However, by allowing node 3 in this case, to code the incoming bits, it achieves the max-flow as shown in Figure 4.1.

The main source of Ant Colony Optimization and routing is a behaviour that is displayed by certain species of ants in nature during foraging. It has been observed that ants are able to find shortest path between
their nest and a food source. This is remarkable because each individual ant which is rather a simple creature, with very limited vision and computing power, finds the shortest path among several available paths is certainly beyond its capabilities. The only way that this difficult task can be realized is through the cooperation between the individuals in the colony. The algorithm is implemented in different sectors like health care, defense etc.

This shortest path is found by ant using pheromone. This is a volatile chemical substance that is secreted by the ants in order to influence the behaviour of other ants. The Ant Colony optimization has been used in solving the different problems like telecommunication networks, load balancing in networks, routing, Hypercube framework, image segmentation, sensor management etc., ACO Can be used for both Static and Dynamic Combinatorial optimization problems.

4.3 ROUTING

4.3.1 Destination-Sequenced Distance-Vector Routing (DSDV)

DSDV is a table driven routing protocol, the basic premise being to determine the shortest number of hops to a destination. The protocol requires each node to advertise its routing table. This table contains all the possible destinations in the network, the number of hops to each destination and a sequence number of the information received from the destination. The sequence number allows routes to be chosen with a preference for more recent information, removing the possibility of loops due to stale routes. In order to avoid large amounts of routing information flowing through the network incremental changes is used to relay only the changes that have occurred since the last dump. The only situation where a node other than the destination may broadcast information about the route is if it is discovered that the route is broken. In this case a route update is triggered with a sequence number one
greater than the last one received from that destination. If a node receives this 1joule and it has an equal or later sequence number with a valid metric, then it will send this information to supersede the 1metric. Route selection criteria are dependent on timing and variation of the received tables. The actual routing is done according to information kept in the internal route table, but this information is not always advertised immediately upon receipt. It is seen that a mechanism whereby routers are not advertised until it likely, based upon past history, that they are stable. Metrics are incremented by one hop and scheduled

### 4.3.2 Dynamic Source Routing (DSR)

DSR is an on demand source routing protocol, in that no periodic packets are required of any kind. This means that the number of overhead packets is scaled according to the mobility of the nodes once routes are established. The protocol consists of two stages; route discovery and route maintenance. Route discovery only takes place if a node’s route cache does not hold a route to the desired destination. The discovery takes place, on demand, by broadcasting a route request packet. This packet contains the initiating and target node addresses as well as a unique request identification number.

Hefei Hu et al (2010) have proposed an efficient routing algorithm (A-DSR) for asymmetric space information network based on the classic DSR routing algorithm. The proposed protocol has been implemented in the QualNet simulator and performance simulation has been conducted as regular routing protocols evaluation. The simulation shows that A-DSR has better performance than DSR.

When a node receives a route request and it is either the target node, or holds a current route to the destination a route reply is generated. If
this is not the case the node adds its address to the route request and retransmits it, both forming a record of the route and allowing the node to ignore the route request if it has already encountered it, reducing flooding. This tagging of the route request, plus in the case of intermediate nodes, their route cache, is the basis of the route reply message and hence routing information.

Johnson et al (1996) presented a protocol for routing in ad hoc networks that uses dynamic source routing. The protocol adapts quickly to routing changes when host movement is frequent, yet requires little or no overhead during periods in which hosts move less frequently.

The route reply is returned to the initiator using the replying nodes route cache, if this exists, otherwise for symmetric links the route is simply reversed, for non-symmetric links the node may initiate its own route request, piggybacking the route reply on top. Route maintenance is shared by all users involved in the routing through receipt confirmation. This may be performed as part of the link level protocol or through setting a bit in the packet header requesting confirmation through whatever means are suitable. If this confirmation is not received then the packet will be retransmitted up to a certain number of times. If there is still no confirmation then a route error packet is sent to the initiating node, identifying the broken link. As many routes may have been received in response to the initial route request, the initiating node may be immediately able to try a new route; otherwise a new route discovery phase is entered.

4.3.3 Zone Routing Protocol

The Zone Routing Protocol is a hybrid (table / on-demand) protocol for a special class of ad-hoc networks known as reconfigurable wireless networks (RWNs). This kind of system has features such as high mobility, a
large network span and a larger number of nodes. ZRP adjusts to network conditions through a single parameter, the zone radius, reducing the cost of updates for topology changes. The routing zone is defined at each node by including nodes whose distance is equal to or less than a maximum number of hops. Those at a distance equal to the maximum number of hops are known as Peripheral nodes, the others interior nodes. Even though the distance is measured in number of hops, it should be noted that increased transmit power will result in a larger radius as more nodes will be within one hop. A node only maintains routing information on those nodes within its routing zone, meaning that the amount of update traffic does not depend on the number of nodes within the network. The zone is discovered through a table driven protocol, the Intra zone Routing Protocol (IARP), which may be any proactive technique. To establish communication beyond the node’s routing zone, an on-demand protocol, the Inter zone Routing Protocol (IERP) is used. This selectively delivers queries from one node to its peripheral nodes, termed border casting.

Stefano Basagni et al (1998) introduced a new routing protocol for ad hoc networks built around two novel observations. Accordingly, the location information in routing tables can be updated as a function of the distance separating nodes without compromising the routing accuracy.

The IERP operates as follows; the source node first checks whether the destination is within its zone. If so, the path to the destination is known, no further route discovery processing is required. If the destination is not within the source’s routing zone, the source broadcasts a route request to all its peripheral nodes. Now, in turn all the peripheral nodes execute the same algorithm; they check whether the destination is within their zone. If so, the route reply is sent back to the source indicating the route to destination. If not, the peripheral node forwards the query to its peripheral nodes, which in turn
execute the same procedure. The overhead for route discovery is reduced by only performing global searches when a major topology change takes place, overcoming link breakage on a local level. To reduce flooding, zones may check if a query has previously reached that zone, discarding it if that is the case.

4.3.4 Link Reversal Routing

It is intended for high mobility networks, or those with dynamic, rapidly changing topologies. The algorithm is not intended to produce shortest distance routing, but instead to maintain a connected graph with a minimum of overhead. This is achieved by localizing the interaction when a change occurs to a single hop; hence a node knows nothing of its position in the graph and the subsequent multi-hop distances once changes have occurred. The graph for each destination is a directed acyclic graph (DAG) routed at the destination, meaning that just the destination may have incoming links only, and acyclic as it contains no loops. A node only reacts to changes when it loses its last downstream neighbour, i.e. it cannot relay a packet onwards. The response is to inform the upstream neighbours that it cannot relay a packet and find a new downstream neighbour if required. This means that route change information is not only transmitted less frequently, but is not transmitted on a network wide basis like other protocols.

An example of link reversal routing is Temporally Ordered Routing Algorithm (TORA). The protocol contains three functions; route creation, route maintenance and route erasure. During the creation phase the graph is built according to a metric based upon “height”. The direction of a link, upstream or downstream, is assigned according to height, i.e. up or down. Links to nodes with unknown, or “null” height are not considered. This forms a directed path. If the network changes then these directions may be incorrect link direction may need to be reversed so that all paths lead to the destination.
This is achieved by reassignment of node heights. In route erasure a node sets its height to null, causing no links to be directed to it. When a node re-evaluates its height, timing is an important factor. Simplified, TORA assumes that all nodes have a synchronized clock used to measure the logical time of the failure, though this need not be the case. The metric used by TORA consists of five elements, the first three define a reference level; logical failure time, unique identity of defining node, and a reflection indicator bit, used to separate the original from the “reflected”, higher reference level. The last two elements; a propagation ordering parameter, and the identity of the node, define an offset.

4.3.5 Power Aware Routing

One of the potential benefits of a relaying system is reduced overall power consumption through the non-linear nature of path loss. There are several issues that may cause concern to planners, both real and perceived, which need to be addressed with regard to the power consumption of users participating in a relaying system. A major factor in the removal of ODMA from UMTS was the perception that users would see a reduced battery life. This will be the case if users in stand-by mode are freely available as relays, as they will be transmitting and receiving when in a non-relaying system they would not. This need not be the case, as the benefits of a relaying system may be realized without the involvement of these inactive units. It may be the case, however, that the use of transceivers purely on path loss will not result in optimal power usage. Some users may have limited battery capacity or low charge. In interference limited system the required transmitted power may be higher than is possible if the routing is base. Several studies and algorithms have been presented with regard to maximizing the battery life of users within an ad-hoc network. Most of these do not consider interference limited systems, though the results are equally applicable to extending the up-time of
these systems in conjunction with the consideration for actual transmitted power. The issue of who should be available for relaying has been considered holistically in systems where stand-by users are available for routing. An algorithm is presented that can increase the time for all users remaining by 50%, by electing users for participation based on energy consumption, and by checking for potential partitioning of the network, increasing the session time of such systems by over 50%. A similar approach is taken where backbone nodes in a totally ad-hoc system are selected in a co-ordinate fashion so as to reduce power consumption.

This approach shows a 15% reduction in power consumption for a negligible reduction in throughput and small increase in delay. Analogously the master role in Bluetooth scatter nets may be swapped according to available battery power, again increasing network lifetime by over 50%. The clustering of sensor networks an optimal, relatively small, number of clusters regardless of whether the network is homogeneous or heterogeneous. The heterogeneous network corresponds to an overlay of more powerful sensors, effectively backbone nodes. Scheduled rendezvous, where users are powered down until a pre-arranged time and radio frequency identification (RFID) used as a low power wake up technique is analyzed. The rendezvous is the most power efficient, while the low power wake up is the most responsive. A hybrid technique is presented to adapt to system requirements connected dominating sets, as mentioned previously, may reduce computation, but also put higher energy requirements upon nodes within the set. Another approach considered is to take into account the bits / joule capacity of a network. Power control in a non-interference limited system according to throughput and bits / joule are presented on a local and centralized basis. It is shown that the optimal transmission distance is a function of the load on the network, and the power is adjusted according to this load. Common power and independent power algorithms are investigated, with the independent power adjustment
giving the best throughput per unit energy compared with common, min, and max power allocation strategies. The bits / joule capacity of energy limited multi-hop networks. It is shown that bits / joule increases with the number of nodes and that for a network with a fixed number of nodes, the number of bits / joule increases as the ratio of ad-hoc to conventional cellular nodes increases.

There may be scheduling variable-rate data to achieve reduced energy per packet at the expense of an increased, but more consistent packet delay which would be advantageous in streaming media applications. This is achieved through on-line look ahead power adaptation to attempt to minimize the required energy and is shown to be close to the optimal off-line approach. These approaches may be considered as an overlay to reduce the power consumption of their laying network. Another approach has been to integrate the reduced power consumption or increased battery life by means of a weighted metric. The Equation (4.1) shows the distance between two nodes.

\[
D_{ij} = \begin{cases} 
W_p \frac{P_j}{P_{\text{max}}} + W_e \frac{E^o_i}{E^R_j} \cdot R_i \cdot R_j \cdot E^R_i \cdot E^R_j = 0 \\
\infty & \text{otherwise}
\end{cases}
\]  

(4.1)

where \(E^o_i\) is the initial energy available to node I and \(E^R_i\) is the residual energy at node i and \(R_i\) the residual capacity at node i. The weights \(W_p\) and \(W_e\) may be adjusted to favour either of the two terms, biasing the routing towards minimum power and battery life respectively. This approach attempts to ensure that energy consumption is evenly distributed across the network. It has been extended to frequency allocation but may equally be adapted to different radio access methods. Equivalently the integrated problem has been addressed by constructing spanning trees or connected dominating sets that are power aware. The trees may be constructed with regard to global or local
efficiency, especially with regard to multicast. For a global approach, less overall power is consumed in multicast with fewer, higher power transmissions. This causes reduced battery life for these users, compared to the local, individual battery approach. More intelligent battery based metrics, however, do result in reduced power consumption. Power consumption of the node is further broken down into processing power and transceiver power, and it is pointed out that the minimum battery routing tends to favour longer paths. For the purpose of this thesis it is considered that while processing power currently forms a considerable part of the overall consumption, with advances in semiconductor feature size reduction, and commensurate square power reduction, this factor will be a negligible fraction in the future. Thermal noise dominates the minimum detectable power, hence with current access methods; it is unlikely that required transceiver power will be reduced by similar technological advances.

4.3.6 Novel Routing Methods

One of the basic preconceptions for wireless ad hoc networks is that the data is sent over a single route. One of the simplest advances that transcend this approach is multipath routing or multipath source routing. Single path routing may under utilize resources and is susceptible to link breakage and possible congestion problems. The idea underlying multipath routing is that by distributing the data over several paths load balancing, reducing congestion and unfair relay power consumption, and route failure protection becomes possible. The problem with this approach becomes how to find the most effective allocation of data between the paths. This has been achieved by modifying DSR, which already discovers multiple routes without exploiting them simultaneously, by applying a heuristic algorithm. An important criterion in selecting the multiple paths is to find node disjoint or independent paths, resulting in a greater aggregation of resources and the
likelihood that performance change in one route will not affect the others. As well as the intended benefits it has been shown that multipath routing can reduce end-to-end delay and reduce control overheads. A more advanced approach that utilizes multiple paths is multiuser diversity for single hop networks or co-operative / user co-operation diversity for multiple hops. With this technique the multiple paths are used in a similar way to multiple antennas in multiple input multiple output (MIMO) or variant systems without the need for physical arrays. Cooperative diversity expects to achieve comparable diversity gains in aspects such as capacity and resilience to multipath fading. As with multipath routing, the system attempts to select independent, uncorrelated channels but utilizes space-time coding to exploit the diversity.

4.4 CLUSTERING NETWORKS

In order to try and reduce the overhead of signaling information and to manage system resources effectively clustering of nodes according to specific parameters has been proposed by several authors. From examining the pole capacity of a CDMA system can be seen that halving the processing gain not only doubles the each user’s possible data rate for a given bandwidth, but due to the lack of interference from the desired signal, increases the throughput of the system. Clustering techniques can facilitate in reducing energy consumption. Network lifetime can be prolonged through reducing the number of nodes contending for channel access, summarizing information at the cluster heads, and routing through an overlay among cluster heads, which has a relatively small network diameter.

As the data rate is proportional to the throughput at a receiver in a CDMA based relaying system we may be able to see an increase in throughput by clustering to a common link by combining the data streams via processing gain reduction, though this phenomenon has not been fully
investigated. It should be noted that this potential benefit becomes negligible where large processing gains are in use.

Clustering algorithms with an unspecified MAC layer are more concerned with reducing the possibility of flooding of routing messages and possible infrastructure assignment, with possibilities such as bandwidth re-use and backbone allocation. Both on demand and table driven routing protocols incur flooding of information in one way or another, a table driven protocol could be designed that incurs similar or less overhead than on demand routing protocols by limiting the polling done by the destinations to the same or less than the polling done by the sources in on demand routing protocols in clustering. The benefit of clustering clearly depends on the sensitivity to flooding with scalability of the protocol. Certain nodes, called cluster heads, are responsible for the formation of clusters. This can be considered as analogous to cells and hand-over in conventional cellular systems.

4.5 SYSTEM MODEL

4.5.1 The MIMO Cooperative Model

The 'MIMO co-operative' model consists in using, between a terminal source S and a terminal destination D, terminal "relays" R shown in Figure 4.2. The latter are charged to cooperate with S to transmit information from S to D. Using the terminal “relays”, it is possible to obtain the same advantage as those obtained with MIMO techniques. The terminal "relays" plays the role of the radiating-receiving antennae. These means of communication are particularly adapted to the Adhoc networks.
To apply MIMO CO-OPERATIVE model, the following stages are used.

1\textsuperscript{st} stage : The choice of cluster source.
2\textsuperscript{nd} stage : The choice of cluster destination.
3\textsuperscript{rd} stage : The choice of the relays of cluster source.
4\textsuperscript{th} stage : The choice of the relays of cluster destination.
5\textsuperscript{th} stage : The test of coverage.

If so, the process will be stopped.

If not, it will build an intermediate cluster and then it is move to the 6\textsuperscript{th} stage.

6\textsuperscript{th} stage : The intermediate choice of cluster.
7th stage: The choice of two groups of the relay of intermediate cluster, one close to cluster source and the other close to cluster destination, then it will go back to the 5th stage. MIMO Co-Operative model is adaptable to whatever network architecture. If so, the process will be stopped.

1st stage: Cluster source

The choice of cluster is based on the distance between the source and the whole of the relays close to it. So that this cluster will contain the source and the relay, both are very close to each other.

2nd stage: Cluster destination

The choice of cluster is also based on the distance between the destination and the whole of relay close to it. Based on this cluster will contain the destination and the relays close to it.

3rd stage: The choice of the relays of cluster source

For the selection of the candidate nodes to the relaying this will take part in the co-operation in the cluster source, the proposed method is based on the distance, that is at the edge of cluster is close to cluster destination in order to preserve energy, where the user has the possibility of choosing the number of relay used.

4th stage: The choice of the relays of cluster destination.

In the same way, the selection of the candidate nodes in the cluster destination will follow the same method, taking into account that these relays must close to cluster source in order to preserve energy.
5th stage: The test of coverage

After making the different clusters and candidate relays, to apply a test coverage. It is used to check if the candidate relay of these two clusters can communicate with each other. If this condition is satisfied this will put an end to this step, if not, this will move to the next stage.

6th stage: The choice of intermediate cluster.

7th stage: The choice of two groups of the relays.

One cluster close to cluster source and the other close to cluster destination. The intermediate cluster is selected based on the distance shown in Figure 4.3.

SIMO : node-source towards the node-destination.

MIMO : cluster source towards node-relay

MISO : node-relay towards node-destination.

With this model "MIMO cooperative" is succeeded to relatively maximizing the throughput and optimizing the power.

Figure 4.3 Choice for the Intermediate Cluster
4.6 IMMUNIZED ANT COLONY OPTIMIZATION

The ant colony optimization takes inspiration from the foraging behaviour of some ant species. These ants deposit pheromone on the ground in order to make some suitable path that should be followed by other members of the colony. Ant Colony Optimization (ACO) is a prototype for designing meta-heuristic algorithms for combinatorial optimization problems. To improve the continuous Ant Colony Optimization, here the mature methods used in evolutionary algorithm and artificial immune system are introduced into continuous Ant Colony Optimization, and a new Immunized Ant Colony Optimization (IACO) is proposed in Figure (4.4). The detailed process of IACO is as follows.

4.6.1 Creation of Initial Ant Colony

In the solution space of optimization problem, the ant colony is created randomly, so the ant initial population can be derived. The site of one ant individual is corresponding to one point of solution space, which is one solution vector.

4.6.2 Fitness Functions of Ant Individual

The fitness function of individual is generally a kind of transformation of its objective function. The purpose of this transformation is not only to guarantee the fitness value of each individual positive, but also to maintain the diversity among individuals.
Initialization

Extrinsic Cycle Start, K=1

Random Distribution Ant Colony

Fitness Computing, Record the best fitness

Internal Cycle start, s=1

Probability move of ant individual

$S = S + 1$

$S < S_m$

Hormone update to each Ant

$K = K + 1$

$K < K_m$

Output Result

Figure 4.4 Basic flow Chart of Continuous Ant Colony Optimization
4.6.3 Probability Moves of Ant Individual

The probability move of Ant individual is the key operation of algorithm. Its move probability can be expressed as follows.

\[ P_{ij} = \frac{[\tau_j]^i [\eta_{ij}]^\alpha}{\sum_k [\tau_k]^i [\eta_{ik}]^\alpha} \]  

(4.2)

where \( \tau_j \) is hormone intensity of Ant individual. At initial stage, it is a constant, which is \( \tau_{i0} = c \). In this study, we take \( c = 0.001 \), \( \tau_j \) is related with \( f(i) \) through \( \Delta t \). \( \eta_{ij} = f_i - f_j \), which express the modification quantity of objective function after the ant individual moves. When \( f_i = f_j \), is occurred, the movement should be repeated, until they are not equal. The \( \alpha \) and \( \beta \) are two variables, which ranges are as follows, \( 1 \leq \alpha \leq 5 \), \( 1 \leq \beta \leq 5 \).

4.6.4 Mutation Operation

Here, the mutation operation is a kind of adaptive Cauchi mutation, the form of which is as follows. Suppose one individual of the population is \( X = (a_1, ..., a_4) \), the new mutated individual is \( X' = (a'_1, ..., a'_4) \), then the component of the new individual can be described in Equation (4.3).

\[ a'_i = a_i + \sigma_i \cdot T \cdot C_i (0,1) \quad (i = 1 \sim 4) \]

(4.3)

where, \[ \sigma_i = \frac{1.0}{\sqrt{\beta_i F(x) + \gamma_i}} \quad (i = 1 \sim 4) \]

where, \( \sigma_i \) is the standard deviation of the parameters; \( C_i (0,1) \) is the Cauchi random num \( F(X) \) is the fitness of individual; \( \beta_i \) and \( \gamma_i \) are two parameters, \( T \) is a adaptive parameter, which description is as follows in Equation (4.4).

\[ T = \frac{T_0}{F_{max} - F_{min}} \]  

(4.4)
where, $T_0$ is the initial parameter, which value is 2.5, $F_{\text{max}}$, $F_{\text{min}}$ are the maximum and minimum fitness of the current population. The adaptive mutation can make the disturbing extent of mutation adaptively changeable through the computation iterative extent, so the search performance of the whole algorithm can be improved.

### 4.7 SIMULATION

Table 4.1 Simulation parameters for ACO

<table>
<thead>
<tr>
<th>Transmission medium</th>
<th>250.0 m (NS2) default</th>
</tr>
</thead>
<tbody>
<tr>
<td>Queue length</td>
<td>250</td>
</tr>
<tr>
<td>Simulation time</td>
<td>70 s</td>
</tr>
<tr>
<td>CBR packet size</td>
<td>512 bytes</td>
</tr>
<tr>
<td>Iteration</td>
<td>100</td>
</tr>
<tr>
<td>Amount of pheromone</td>
<td>0.52</td>
</tr>
</tbody>
</table>

![Figure 4.5 Trace of the Different Constellation Order to Maximize the Throughput](image)

Figure 4.5 Trace of the Different Constellation Order to Maximize the Throughput
Figure 4.5 represents the characteristics between signal to noise ratio and throughput. The graph of various constellations MQAM (Multiple Quadrature Amplitude Modulation) shows that for each interval of SNR, to find a constellation which maximizes throughput. There are three possible constellations are 4-QAM, 16-QAM, and 64-QAM.

- For SNR ([- 20, - 4] dB) the best constellation is that of 4QAM.
- For SNR ([- 3, 6] dB) the best constellation is that of 16QAM.
- For SNR ([7, 20] dB) the best constellation is that of 64QAM.

This chapter concludes that the best constellation used is an adaptable constellation. After choosing the best constellation so as to increase the throughput, we need a function which will be the measurement of the mutual satisfaction of the maximization of flow and the optimization of flow and the optimization of energy.

The objective is to maximize the flow of the system by maintaining the report/ratio of signal to noise optimal (SNR) with an aim of optimizing the power of transmission of the data. Power control is essential for the operation of wireless networking, because the power of exit for each user contributes to the interference known by others. The productive flow is strongly centered by the product of rate of transmission of information and by the rate of chances of success of the transmission.

In Figure 4.6, it is seen that the energy consumption of pure network coding is smaller than pure relaying. But the energy consumption is even more reduced by introducing a small number of teams, the lowest energy consumption is found when using $T = 4$. If the number of teams becomes too large, the energy consumption goes up again. But note, having more teams will lead also to an additional delay. Nevertheless the introduction of teams allows a flexible tradeoff between delay and energy.
Now wireless technology that would use nearly no power in the idle state is assumed such it is realized Digital Video Broadcasting - Handheld (DVB-H). Introducing network coding would use a significant amount of additional energy as given in Figure 4.7. But also here the usage of teams helps to reduce the usage of teams the energy consumption. By using $T = 24$, the overall energy consumption will be even smaller than the pure relaying.

**Figure 4.6** Energy Consumption versus Delay for the Pure Relaying, Pure Network Coding

**Figure 4.7** Energy Consumption Vs Delay for the Pure Relaying, Pure Network Coding, and Network Coding in Power Values of Ideal WLAN Type ($P_{idle} = 0$)
4.8 SUMMARY

MIMO technology is introduced in a virtual way in order to transmit in beam formation from the source towards the destination, while benefiting from the existence of the various nodes and while exploiting diversity in an Ad hoc network for the improvement of QoS. The proposed algorithm has chosen an adaptable constellation MQAM for each interval of SNR which has given us good improvement as to maximizing the flow (throughput) and to optimizing the power. The combination of cooperative wireless networks and network coding is advocated. The combination of those two approaches is beneficial for the throughput, delay and the energy consumption. To improve the performance of those continuous ant colony optimizations, the principles of evolutionary algorithm and artificial immune algorithm have been combined with the typical continuous Ant Colony Optimization, and the adaptive Cauchi mutation and thickness selection are used to operate the ant individual, so a new Immunized Ant Colony Optimization is proposed.