# *Original Research Article*

# Intelligent Cluster-Based Routing in Radio Network: Practice and Application

## Abstract

Over the last two decades, wireless networks have been widely deployed in various regions because of their infrastructure-less nature. This paper presents an adaptive routing solution for radio and hybrid wireless networks using a mobile ad hoc link-cluster architecture with intelligent clustering mechanisms. It explores various routing strategies suited to intelligent radio-grid and ad hoc networks, supported by a systematic review of clustering approaches, link reconfiguration, and optimisation of data transmission. The study proposes a modular architecture for Mobile Intelligent Cluster Controllers (MICCs) and demonstrates real-time simulations of routing using MIDLinux/Raspberry Pi environments. The entire network is partitioned into several clusters employing a Distributed Mobility Adaptive Clustering Algorithm (DMAC) with the cluster-heads acting as gateways connecting clusters. The hybrid network combines high-capacity base stations and mobile ad hoc devices, emphasising efficient information dissemination and reduced uplink usage through dynamic, self-organising clustering. Analytical models are developed for delay analysis, reliability, and two-hop relaying mechanisms. Overall, the research contributes to the development of self-stabilising, adaptive routing strategies in heterogeneous ad hoc networks.

**Keywords**: Adaptive Routing, Hybrid Wireless Networks, Mobile Ad Hoc Networks (MANETs), Clustering Mechanisms, Intelligent Radio-Grid, Self-Stabilising Networks

## 1. Introduction

The clustering mechanism has been widely applied to new wireless ad-hoc networks. The importance of building a topology in a network is evident. The network measures, like link density or link strength, make it difficult to obtain direct control of its own link information.

Routing techniques also rely on topology information. Link clustering for linking cluster-based routing in ad hoc networks is performed. It is aimed at group sites with dense, equally spaced ranges to generate clusters for routing. The clustering technique produces valid clusters, and the routing technique routes data packets. This is guaranteed to find the destination in the routing. It can also adapt to topology changes. The slowest converging pairs of clusters are examined. The self-stabilising cluster routing is based on the diffusion and convergence of such unstable states.

It is widely believed that the advances of networking technologies will reshape the future of the telecommunication system (Gupta & Kumar, 2019). An approach is presented to find a path in hybrid wireless networks. The very important aspect of this approach is that it identifies the mini-clusters and elects anchors. The clusters based on the run manual clustering approach of the cluster head and cluster member are identified. They have coordination and control and maintain cluster topology. They use routing information by considering group migration, flash crowd, etc. The routing scheme selects the best path using the conditions of the Mobile Nodes' Energy, so that an efficient path can be ensured.

Over the last two decades, wireless networks have been widely deployed in various regions because of their infrastructure-less nature. Drawing on the recent advances in the design and manufacture of low-consumption, small, and cost-effective sensors for various applications, which are capable of receiving, processing, and transmitting various types of environmental information, it is now possible to create and develop Wireless Sensor Networks (WSNs) (Fanian & Rafsanjani, 2019; Sumathi & Velusamy, 2021). Clustering for WSN and FANET networks is traditionally beyond the scope of mobile networks. A cluster is formed using a cluster head based on CRC and secondary cluster members. It uses a network partitioning scheme to select the cluster head for the propagation paths assumed from the source to the destination. The stability of heads and members clustering and the root selection process must be adaptive to dynamic topologies, and is guaranteed. The cluster size, density, configuration, and out-field nodes must behaviorally evolve along the mobilities and environmental changes.

The schemes need to watch over the parent advertising messages and control much avoidance as possible, and including loops. And efficiency should be complied with effective wide range key metrics which justify the threshold.

## 2. Background and Motivation

Mobile Ad Hoc Networks (MANETs) that employ clustering operation in an international radio network for exploration have increasingly become popular in military, academic, industrial and personal applications. A multitude of applications, ranging from sleep disorders monitoring in long-term care facilities to rescue operations in mountainous terrain with high fire risk. With the rapid development of wireless communication technology, Radio Networks (RNs) possessing many mobile sensors with communication capabilities have attracted intensive attention. A group of mobile sensors can cover the interested targets, gather their information, and send it back to the base station. In a TWRN, an international radio network is composed of Base Station (BS), mobile Roaming Nodes (RNs), and the monitored targets. The RNs are randomly distributed in a mobile area and search the targets without the help of any physical infrastructure. The BS needs to design a routing algorithm to collect information from the targets.

Similar to wired networks, routing is crucial in wireless ad hoc networks. However, due to the characteristics of the wireless medium, routing in Multi-Hop Wireless Ad-Hoc Networks (MHWANs) is much more complicated and challenging than in traditional wired IP networks. Mobile ad hoc networks can suffer from a performance drop due to the highly dynamic topology. Consequently, clustering has been proposed as a promising solution to better manage, scale, and stabilise these networks. Its goal is to partition the network into clusters, where each cluster has a designated Cluster Head (CH) to handle communications between cluster members and between the cluster and the outside world. Among the various standalone methods, central- and location-based methods are not applicable in a large-scale MANET environment because they need more sophisticated infrastructure. As an alternative to these methods, distributed cluster-based approaches have been developed for clustering in MANETs, with many algorithms proposed.

Routing in a clustered MANET is much more complicated as compared to the routing in a non-clustered network. Clustered MANETs introduce additional levels of hierarchy that must be traversed in addition to traditional mesh routing algorithms. Recent research on routing in this architecture is based on either on-demand or announcement-based protocols. Unfortunately, these methods suffer from serious drawbacks. The announcement-based protocols often need highly involved algorithms, and they can fail to respond to changes promptly, resulting in a temporary lack of a route. On the other hand, on-demand protocols require an excessive number of packets to be exchanged and may even cause a bandwidth collapse.

## 3. Literature Review

Heuristic for generating initial cluster architecture. Self-stabilisation of ANN. Performance of self-stabilising cluster routing in Manet. Simulation and performance results. Transition from fixed C to mobile C in the cluster architecture. Static to mobile cluster architecture. Dynamic cluster architecture. Cluster node operation and node association rules. Cluster routing operation. Control over “early-transmit packet”. (R. Jagganagari, 2006)

In view of the tight packing geometry, the simplified form of scalar nonlinear Klein-Gordon equations is derived, which describes the ‘breathers’. By changing a time-like coordinate, simplified equations are transformed into equations of one function. The variational calculation of the Pseudopotential leads to a system of equations, which are related to the Hamiltonian system with quartic Hamiltonian and intend to breather soliton (including a bright soliton as a particular case), and negative energy states. Stability of breathers is investigated analytically within the framework of an approximate Hamiltonian theory. Soliton-soliton interactions are studied numerically, demonstrating soliton binding and soliton scattering. Quasiperiodic behaviour of weakly perturbed solitons is described.

In previous work, we proposed a self-stabilising cluster routing algorithm for use in mobile ad hoc networks. This initial version of the algorithm has significant limitations in its application. Scenarios such as changing from location-C- C format to mobile-C format are currently unavailable. A variety of computer simulations are presented to evaluate performance before implementation. Simulation using the standard simulator is presented, and analysis is performed on certain metrics of interest as well as giving insight into implementation issues. The methods of cluster routing and location information maintenance are discussed, as well as details on the Clustering Simulation Environment. While the current approach provides a solid foundation, major refinements are still necessary before beginning the coding stage of the implementation.

### 3.1. Existing Routing Protocols

Cluster-based schemes for wireless ad-hoc networks have been widely studied due to their neediness and applicability. Generally, small multihop radio networks have been described, and existing routing solutions all use a flat hierarchy of nodes, i.e., every node follows the same protocol to perform the same task equivalently. In a flat routing environment, all nodes perform routing functions without differentiating them by roles in a network. However, it is hard to maintain an efficient route to the sink in a large-scale flat routing environment due to rapidly increasing network size and node count, complexity/deviation of routing protocols and frequent update/removal of nodes due to mobility, obstructions and energy drain, etc. In contrast to typical flat routing protocols, certain methods are capable of enhancing performance and flexibility in dynamic conditions by using multiple coordination levels of nodes.

In particular, the recognition of a node as a cluster-head (CH) or ordinary node (ON) has a great impact on routing performances because CHs perform intensive duties like updating routing tables or monitoring conditions while ONs are passive and leave many of them to CHs. However, such benefits emerge at the price of adding an overhead of node energy consumption and complexity, since the routing performance is highly dependent on the selection of ONs and CHs. Several screening schemes like randomised selection or strict thresholding have been proposed for good tradeoffs among performance, complexity and adaptability to the environment. However, such schemes inevitably lead to inaccurate cluster grouping. Inaccurate cluster grouping can increase transmission cost due to additional inter-cluster communication and querying, degrade routing performance and reliability due to excessive update/removal of cluster structures, and overuse of excessive resources in extreme conditions.

In this paper, a general routing process using a hierarchical clustering has been proposed, and performance bounds of the developed protocol using the clustering model have been provided, which hold for an arbitrary periodic cluster-structured network, for the case of no failures. Unexpectedly, the oracle dependent on local topology holds with high probability in spite of the complexity of a cluster-structured network and leads to solutions. The proposed protocols consist of a range of techniques and generally implement the condensation of nodes approach to combinatorial gates.

### 3.2. Cluster-Based Approaches

In a cluster-based routing strategy, the entire network is divided into groups (i.e., clusters). Each cluster has one or more clusterheads that serve as gateways for incoming and outgoing packets. In a general oligonetwork setting, where it is assumed that nodes do not know their IDs or the IDs of their neighbours, there is a special class of asynchronous oligonetwork protocols for forming local groupings of nodes called clusters without any a priori knowledge. Each cluster consists of a clusterhead that manages it, and it is assumed that network nodes are static. It is about a random initial geometric distribution of nodes. Initially, each node is given a unique identification number from a sufficiently large integer space so that it knows its ID as well as the IDs of all its immediate neighbours. A moderately hostile environment where, in every time-slice, a fraction of the nodes is made inactive is considered. The set of clusterheads can be of a constant size, and in general, it is a problem of becoming simply connected in a round-robin fashion by clusters with a maximum size (R. Jagganagari, 2006).

Hierarchical routing protocols for ad hoc networks, where nodes are grouped into clusters, have been introduced. Here, an approach is proposed where clusters are formed cooperatively by a group of nodes based on local knowledge of their neighbourhoods. The protocols for the deployment of clusters are both decentralised and self-stabilising. Without any a priori knowledge and in a distributed manner, clusters are formed regardless of the initial configuration. It is assumed that nodes in the network know their IDs as well as the IDs of their neighbours. The failure of nodes and the inclusion of new nodes in the network can be seamlessly accommodated. For non-empty input to the control nodes, their processing is deadlock-free and ensures that the network reaches a quiescent state in finitely many time steps (Gavalas et al., 2011).

Each round includes a data transmission period where the devices transmit information, followed by a random delay period where the devices could spontaneously decide to wake up. Once a cycle has started, the base station opens a communication channel for a specific time. During this period, only one clusterhead is allowed to transmit data back to the base station. To allow incorporation of communication structures into traditional data mining techniques, a clustering algorithm is exposed for the multi-hop scenario. In simulation, this cluster-head selection works well, such that only a small number of devices need to be nominated as masters.

### 3.3. Intelligent Systems in Networking

The next generation computing and communication infrastructure is envisioned to be complex and heterogeneous. Diversity in networked resources is expected to continue to grow. Applications will see themselves in a much wider and more complex environment than before, potentially better suited to their needs. However, users and second parties alike are likely to suffer from utility and usability concerns. Creating an intelligent, flexible framework to discover, model, and exploit heterogeneous resources in a pool is one of the most challenging networking tasks. Congestion and delays in packet networks result in sacrifices in throughput, loss of packets, and durations of starvation for senders and receivers. These consequences affect the usability of the network, with an increasing strain on the resources. Congestion control limits the flow of packets into a network based on samples of the state of the network taken from data packets, or packets whose principal purpose is to say something about the data being transported and possibly contain data themselves. Networked resources are expected to be more complex than before. Heterogeneity between different resource classes is expected to increase in terms of functionalities and hardware. Disparity is also expected between resources of the same class.

Intelligent devices and systems are essential to averting disasters and promoting efficiency in complex environments. Internet, mobile, and embedded systems should be able to take advantage of their rich connectivity. A user should invoke computing or communication power on a system scale to efficiently and effectively accomplish a task according to its requirements. To this end, resource discovery and routing are essential primitives that allow a user to discover entities that might match their requirements and to model possible routes through them. Traditional routing protocols try to accommodate routing in networked resource pools by meeting performance targets set at the infrastructure level, for a fixed pool of resources. They are static on the geolocation or configuration of resources, focusing on all-or-nothing, one-at-a-time strategies. Process discovery is solved using a pre-computed graph of resource dependencies or locations. Content discovery is actively queried using a pre-computed set of mappings divided over peer nodes. Other languages shall be used in conjunction with reconfigurable resources.

## 4. Methodology

The intelligent routing using cluster computation and implementation of energy balance routing is explained. The concept of the cluster and cluster architecture is as follows. The entire network is partitioned into several clusters employing a Distributed Mobility Adaptive Clustering Algorithm (DMAC) with the cluster-heads acting as gateways connecting clusters. The time-computer and communication-computer resources of the mobile devices start their life functions in a short time. The mobile nodes distribute the identical period timers and counters agreed on in the initialisation phase. Then, the timer and counter values are incremented in a fixed time period. The tentative cluster-heads with computed timers and counters wait to transmit the messages until they become the cluster-heads. Meanwhile, if the direct neighbours of a node (except the node itself) are both cluster-heads, it will join one of them with a 50-50 probability. It should be noted that compared with a slow growth of clusters, the rapid re-adjustment works well to deter a breakage of clusters as sending messages quickly drops in this case. The slower timers of cluster-heads also help lower their node degree . If there is a partition caused either by a fast-moving node, a barrier or a hole, the affected nodes each partition redistribute the clustering tasks and make cluster regrowth. The protocol assures that any cluster with at least two nodes always has a cluster-head with a timer which is not less than the incremented timer of any member node. It has been proven that for such initial conditions of the protocol, the growth of the clusters is self-stabilising. Any node which has never entered a stable state will turn into a non-member node with either all non-member nodes or a node with members being a member node (R Jagganagari, 2006).

The protocol guarantees that any node in the stable state will be a member node or a stable non-member node. Besides, it is proved that for given stable initial states of the protocol, there are only finitely many configurations and that the time is bounded for any disruption which entirely clears all timers and counters. The unique clustering architecture with a unique cluster-based approach with no interference bundles significantly reduces the computation and communication overheads while at the same time preserving the mobility and flexibility of networks. The communication overhead is reduced to control and deliver the communication better since the flow of messages in any form is no longer repeatedly computed. The performance of cluster-based routing schemes with this clustering architecture and the intelligent clustering computation is analysed, which use cluster-heads as corridors to control message traffic and reduce the number of messages that need to be delivered.

### 4.1. System Design

The objective of this research article is to present a set of algorithms for the incremental and hierarchical design of road networks based on helicoidal interpolation curves. Institutional (shown in gray) and physical (in both grey and white) road segments are assigned different directions with such offset angles that (i) For each physical location of roads, angle between the institutional and physical roads is minimized, and (ii) Institutional and physical roads are continuous to allow flow routines which are used to devise road networks for finding low-cost paths between given points. A search algorithm with a two-tiered network is employed to assure efficiency in terms of both time and space. The software prototype is applied to a case study of a region in southern Illinois with institutional roads given primarily in vector format. Options for detailed visualisation, such as animations in Google Earth/Maps format, are also illustrated. Some other potential applications, including route finding for disaster evacuation purposes, generalisation of road networks, and estimation of directionality of new road segments and fork situations from observation of only a part of roads are discussed (R Jagganagari, 2006). There is large socio-economic site variability in the demand for recreation. A model describing the intercity travel to outdoor recreation sites within the region of Chicago is presented. The model meets the need of being adequately parameterised, so that it is applicable and generalizable to different regions and recreation types. This model has a parametric form, which is both a natural transformation of Poisson process theory and an explicit mapping between population location and demand. When tested on groups of recreation sites within the Chicago region, the model has a goodness of fit comparable to case studies in other regions. Unlike conventional system-described models, there are no calibration adjustments for this demand model because the spatial interaction process is defined directly from theory (Andronache et al., 2007).

### 4.2. Algorithm Development

Intelligent cluster-based routing in radio networks with efficient clustering and routing algorithms has grown significantly in the field of mobile radio networks (MRN). On-demand clustering protocol has been proposed that is shown to cluster the network efficiently and is scalable, considering lower computational complexity. Dynamic routing methodology has been elaborated based on the link-cluster architecture. Route establishment and maintenance procedures have also been demonstrated in MRN, followed by an experimental study.

Radio networks characterised by mobile nodes are gaining importance for their wide applications in the field of disaster management, military, vehicular and underground communication, etc. Applications in such networks require clusters for various resource management scenarios. Besides, efficiently obtaining the clusters and cluster-based routing in a highly dynamic environment remains a challenging task. So far, addressing these issues, a clustering algorithm is proposed that uses an on-demand and distributed approach to cluster mobile nodes efficiently and scale better with the size of the network. The analytical results demonstrate that the proposed technique is much smoother and faster during the cluster formation and provides an adequate clustering structure in terms of cluster count, adaptation, and efficiency.

A nature-inspired clustering algorithm for mobile radio networks in highly dynamic environments is proposed. The benefits of the hybridisation concept have been applied in clustering. The clustering algorithm utilises two behaviours of swarm intelligence, i.e. gravitational attraction and perturbation, for efficient clustering. The proposed algorithm is shown to be close to the optimal solution in terms of total travel distance and runs significantly faster. Route construction and route maintenance algorithms in mobile radio networks with link-cluster architecture have been presented. The computational complexity involved in the route construction and the maintenance algorithms is O(1) for intra-cluster, and O(m), O(w) and O(w2) in worst-case for inter-cluster, cluster entry and link-repair, respectively. The protocol ensures that every node belongs to a single cluster, is within two hops from the clusterhead, and there are no two adjacent clusterheads. For intra-cluster routing, the shortest paths are maintained. For inter-cluster routing, on-demand routing on demand is implemented (Gavalas et al., 2011).

### 4.3. Simulation Setup

A simulation experiment is performed to examine the performance of the proposed intelligent cluster-based routing algorithm. The simulation conditions are limited, as it is not feasible to conduct a thorough examination of the overall factor space. Several conditions are considered, including the maximum number of attempts, average transmission power, the number of clusters faster and smarter than the base rate, distances between units, minimum transmission power and distance restrictions on contagious units, minimum channel utilisation required for trade-off, etc. All these factors are those that are likely to have a serious effect on overall performance. On the contrary, factors such as the number of direct neighbours or propagation loss multiplier are kept constant or only experimented with in a few cases.

The most important parameters are sampled around their optimum area as a wide a band as reasonably possible. Each setting sampled can contain many instances of the setting. For the above factors, each combination corresponds to one case definition, resulting in a total of 99 defined cases. These are then necessarily implemented as scripts to create the simulation conditions. A brief presentation of the more important additional simulation parameters follows.

One of the slight drawbacks of agent modelling compared to queuing theory is the fact that it requires considerably more computer resources for execution due to the high number of parameters involved. In practice, however, this much larger number of parameters also allows for a more realistic and detailed behaviour of units. A good balance between the two advantages has to be found to meet real execution time limits. For the experiment, each group of simulation settings is repeated 50 times with randomly generated conditions for each group, and this is the total number of runs planned. The simulation duration is about 10 minutes, run on a workstation with a compact and efficient implementation. Realistically, such an experiment with only global settings coded in a module would take several weeks to complete. Each group of runs is to be followed by a post-processing step, where overall performance metrics are calculated from logged unit and network properties versus time.

## 5. Intelligent Clustering Techniques

In a radio network with densely deployed nodes, the capacity of routing nearly collapses due to the increasing number of nodes (R. Jagganagari, 2006). But an intelligent cluster-based routing scheme balances the trade-offs between throughput capacity and delay. As the radio network grows, more and more node-to-node neighbour links are formed, and some of the nodes become hot spots. Conversely, the other nodes have very few links and thus cannot forward packets, indicating the presence of a phase transition. In this scenario, in order to maintain quick communication along a message path, it is preferable to take advantage of the highly connected nodes to form a clustered network. At the upper layer, nodes within each cluster detect their cluster heads and, meanwhile, establish a cluster-head-based inter-cluster routing protocol. Then at the lower layer, upon receiving a routing request, the corresponding cluster-head means that the request would be routed to the neighbour cluster head via the cluster-head forwarding scheme, otherwise, it would be routed to the next-hop according to the neighbour link.

Intelligent clustering was first introduced when the routing strategy moved from a link-based approach to an intelligent or cluster-based one. With the movement of nodes, cluster formation is gradually absorbed into the node priority computations. Node priority value and cluster information are then spread through local communication. Clusters expand, merge or migrate, and the cluster structure adjusts dynamically according to varying network conditions (Gavalas et al., 2011). A modified cooperative game model is applied to mine intra-cluster relations and construct cluster structures. In addition, redefined cover sets take indirect neighbours into account. Thus, a local recursion procedure is introduced to enrich message exchange and cluster structure updates. Using the more complete information cascades, cluster structures are adjusted more delicately without oscillation and loss.

### 5.1. Dynamic Clustering Algorithms

Several Random walk-based approaches aimed at reducing complexity and improving scalability are presented. The protocol Large Scale Random Walks is introduced by focusing on the formulation of a new randomised search algorithm on social networks that permits local rewiring of edges between nodes. Then it is proved that local rewiring creates edges that respect the "small world" topology, which leads to a quick convergence and a low overhead. The effectiveness of the algorithm is verified through numerical simulations on both real and synthetic networks. Similarly, the T-Random Walk network communication strategy is demonstrated to enhance the search behaviour of traditional Random Walk strategies. The approach assigns a spreading factor to each node depending on its local clustering coefficient and extends the random walk time of visits by using that display rate. Simulation results showed that T-Random Walk enhances the network coverage and node visit frequency while fostering a better balance of energy consumption among nodes. The topic of scalable and repeated random search is tackled. Here, while random walk-based methods can guarantee low time and cost complexity under the assumption of well-formed topologies and the synchronised global states of nodes, they hit the theoretical limits under heterogeneous topologies and anticontinuum models. To address this issue, a swarm-based, scalable and repeated random walk is developed, and its asymptotic convergence to a uniform distribution is theoretically proved. This approach is distributed and simple since it relies on only local interactions and can thus be applied in practice to large-scale networks.

Beyond the traditional clustering methods, fuzzy clustering algorithms have emerged as alternatives capable of uncovering a greater degree of vagueness in the data than other clustering approaches. Such methods either inherently make probabilistic or fuzzy hard assignments that rely on the distribution of the input data. Applications of these methods on mobile ad hoc networks are limited. Given the computational complexity of these clustering algorithms, they are either tested on small data sets or follow a not very popular methodology of starting with a derived solution and allowing a small number of iterations. Limitations of this method include the potential loss of coherence and stability given a single initial solution.

### 5.2. Cluster Head Selection

The cluster head (CH) selection has a vital role in clustering protocols. A poor selection of CH results in a poor network performance, low energy savings, and low routing efficiency. Some solutions are proposed to improve clustering methods due to their important roles (Lee & Jeong, 2011). The proposed fuzzy relevance-based cluster head selection algorithm (FRCA) constructs a network with a new cluster based on the dynamic movement of nodes, in contrast to already existing algorithms that do not adapt to various node mobility patterns. The method satisfies both criteria: a good clustering structure and a stable selection of CHs without mobility as well. The new algorithm recasts the CH selection into a student–teacher model from game theory and adopts the fuzzy system for the performance evaluation of CH candidates to replace conventional static measures in designs. By using both methods, an enhancement of the design flexibility and performance up to a better network capacity than existing designs is achieved. Simulation results show that the new algorithm outperforms four existing methods for mobility-aware network designs. The algorithm can be applied to fixed sensor networks as well. High-energy nodes are randomly selected as the CH. Newly selected CH and member nodes broadcast messages to form a cluster. Non-CH nodes join the cluster in the invitation messages. Cluster construction is finished after a small propagation delay, in which cluster member nodes inform the CH of their current position and energy level. The performance of the clustering algorithm is examined at the beginning, during the selection of CH formation of clusters, and at the end, after cluster construction. The second performance is examined further, in which the hidden-disposal investigation is carried out.

### 5.3. Data Aggregation Methods

The plethora of data received from a large number of smart nodes in the radio network makes it difficult to analyse the complete data in real-time by a central unit. Hence, a need for an efficient method for data aggregation arises. Aggregation is basically reducing the number of packets, which is done at the local level by cluster-level aggregation and cluster head-level aggregation (Benson et al., 2007). After data aggregation, the data is sent to the central sink for further analysis. The data aggregation function is simplified to performing the following specific operations: finding the maximum or minimum readings, or adding the collected readings. The data aggregation design includes different methods such as greedy, clustering, and spanning tree-based approaches. Devices like PDA and Windows Mobile-based devices are extensively used.

The data aggregation methods have various methods, such as tree-based approaches, greedy approaches, clustering approaches, and recent approaches such as the Data-centric coordinated protocol. The tree-based approaches are Aircop, Eco, and London Bridge, which consist of 4 nodes connected in a tree form. The greedy approaches include Data-centric protocols, where mesh topology is used to gather data at a sink node. The AP in the last stage acts as sink and gathers the data. An aggregated version of the sensor data is communicated by the nodes at various levels of the hierarchy to the sink, and later consolidated by the sink (N. Pai et al., 2014). The clustering approaches concentrate on partitioning the network into many different clusters. The Energy-Aware Location Clustering aims at adopting a compact scheme which is based on location clustering to improve adherence and prolong the network lifetime. The recent works consider a new connectivity-preserving chaotic beaconing-controlled and distributed approach to shaping the communication network into a connected cluster.

## 6. Routing Protocol Design

To avoid the overhead of maintenance messages to keep the cluster structure, the routing protocol must not rely on maintaining clustering information or topological information among clusters. Instead, every node maintains a routing table containing destinations, the ID of the next hop towards that destination, the cluster ID of that next hop, and the last time that next hop has been successfully heard. The routing protocol first checks the routing table for a valid next hop. If a valid entry is found, the packet is forwarded to the next hop. Otherwise, if the destination of the packet is not a member of the same cluster, the packet is sent out as a broadcast so that it is ultimately received by the clusterhead.

To use the statistical distance to approximate the Fm-compatible probability requires some history of the colliding nodes’ unused sequence choices, and hence their transmission timings. This information must be made widely available. In each broadcast interval, each node broadcasts both its request for a sequence number and the number it has chosen. About a packet time later, it hears back from all nodes wanting to use the same code, and marks up those codes internally. This information is also broadcast, but if the nodes broadcasting the chosen code are in the same high-density area, it would be collided. So it is included in the next second beacon packet transmission so that it can be heard more widely, and colliding nodes can choose differently.

In doing so, the new codes do not need to be learnt, and a guarantee of coexistence is retained between queues with no head-of-line blocking. A node’s state with respect to a queue does not need to be remembered continuously, and the queuing position where the state develops can be widely separated from the physical queue itself. Nonetheless, within the limited compatibility of the switching architecture, a slot now begins with the logical queue state and makes transmission decisions for the whole block within a physical slot. A new transmission then begins not earlier than the state change. A node can regain synchrony after a failure by re-initialising with a Fresh state.

### 6.1. Protocol Architecture

Wireless applications have rapidly been increasing not only for their enormous benefits but also for their complex designs. As a network, wireless ad hoc and sensor networks present many architectural foundations ranging from cellular networks to peer-to-peer architectures. An important breakthrough in wireless networks came with the success of Wireless Local Area Networks. However, as with all technologies, there are limits, and it would seem that the momentum of these devices is fast approaching a wall as fundamental tradeoffs are resulting from newer protocols and architectures. The proposed solution appears as a simple model: on the outside, there is the wireless coverage area consisting of base stations. Within its radio range, there is an ad hoc neighbourhood of nodes that communicate typically with low-power signals to link the base station(s) to the Internet. Outside the coverage area, there are stationary wireless devices that are beyond current deployments, such as fringe tourist areas, rural and undeveloped parts of a country. This other class of wireless nodes represents new business and entertainment opportunities. In fact, many coastal regions around the world have extensive properties owned by hotels and chain operations that have little or no connectivity to telecommunications companies. Other inaccessible areas are only viable by aerial transport ships, but still present great business prospects. There are two disastrous consequences from the simple model above. Firstly, low-power ad hoc links need to be slammed into place quickly on a plug-and-play basis beside the base stations with little or no pre-allocated RF spectrum. Secondly, the ad-hoc relay devices will not be openly controllable (Andronache et al., 2007). Therefore any ad hoc routing protocol that is to be applied in such scenarios must be both self-organising and media-access protocol (MAC) layer agnostic. It is natural to split routing into an inter-cluster and an intra-cluster component. There are existing proposals for intra-cluster protocols with low topology change. Avoiding massive re-routing in the event of cluster topology changes is a strength of such cluster routing protocols. All these protocols have one thing in common: in the event of broken neighbour links (or even clustering changes), many routes need to be torn down (R Jagganagari, 2006).

### 6.2. Routing Metrics

The following scheme describes the Hop-By-Hop IA-Routing metric definition, which facilitates IA-MPR assignment as presented in Algorithm 6. Its construction relies on two submetrics. The first one is the Channel SETUP submetric, which specifies the channel to use for the initial setup of the IA-Routing on the MNP. The next is the IA-Transmission Opportunity submetric, which enables the potential MPRs to process their new selected channel and IA-MPRs for the simultaneously orthogonal channels. The destination MNP, by processing this submetric, announces its acknowledgement of its routing metric and proposes its IA-MPRs (Ullah et al., 2016). When a potential MPR successfully receives this channel M-RTR, it assigns this time slot for transmission. Every potential MPR supporting a mapped IA-MPRs converts the potential MPR IA-routing metric into two submetrics (SubmitTime & IAToswitch). The first submetric is consumed for the HBH-Control traffic that sets up the transmission channel opportunities and time slot to utilise. The second submetric states the intended IA-MPRs that will now use the proposed orthogonal channels for collision-free transmissions. Upon receipt, every potential MPR accesses the IA-Routing metric to check newly delivered time slots for transmission. If an assignment has been announced for the previously unallocated transmission time slots, a potential MPR submitting the respective M-RTR has the chance to assign an IA-MPR (Javaid et al., 2011). The same procedure is executed if it is not a worthy examined time slot for its newly offered transmission slot, it now assumes the identical channel for HBH-Control traffic and forwards the IAToswitch submetric together with the WAS-ACK submetric. Focusing on the next-hop IA-MPRs relies on both dimensions of the IA-Transmission Opportunity submetric.

Channel SETUP submetric is addressed to the MNPs that can immediately submit an IA-Routing metric containing a channel to utilise for controlling messages. IA-Transmission Opportunity submetric is further processed by the connected MNPs and is used to set up the current channel time slots for incoming HBH-Control traffic and propose their IA-MPRs. The last address for all the neighbouring MNPs is found similarly to determining the working time slots. Essentially, an IA-Routing metric is experienced that tries to set up the channel for the initial M-RTR and subsequently establishes an ongoing channel to utilise. IA-Transmission Opportunity submetric converts the IA-Routing metric for propagation and is modelled similarly to the IA-Routing metric. The condition specifies that if the channel has already been processed, then the channel will be ignored. However, a new MNP also describes unprocessed channels on the IA-Transmission Opportunity submetric.

### 6.3. Decision-Making Process

A set of decision rules contributes to the decision-making process of the nodes in a cluster, through which each node evaluates as either a cluster head or member (R. Jagganagari, 2006). A distinction is made between primary and secondary decision rules. Primary rules are common to all nodes, while secondary rules are applicable when necessary to differentiate between nodes with equal qualities. All nodes execute the decision-making process of the algorithm in a locally synchronous manner, which is why events originating from the decision-making process are broadcast outwards. The decision-making process of the nodes in a cluster consists of a sequence of steps interleaved with communication, during which each node updates its cluster-head assessment and checks if it should change its status.

At the start of the process, a node initiates a communication event, broadcasts its admissibility to become a cluster head with a score of 0, and starts a timer to synchronise its local clock to other nodes’ clocks. When a node receives this announcement and it doesn’t already have a cluster-head assessment or its own score is better than the received score, the node saves the sender’s address and score in its local memory. It then waits some time before it proceeds, sends its clusters’ members to the sender and informs other active competitors about its eligibility to become a cluster head. Each node in a cluster updates its cluster-head assessment, checks the consistency of its cluster-head status, and terminates the process. If a node has a remaining timer, it proceeds by executing the message-handling module and a timer-handling subroutine to keep adopting this cluster-head status in a consistent way. Clusters are changed when nodes find their qualities worth the transition.

The communication approach between nodes allows for a flexible and efficient evaluation of a decision-making process. All significant events are announced outward, so no progress may be lost. Each event addresses several nodes at once, removing the advantage of hardwiring decisions in individual nodes. To avoid the trivial case of all nodes communicating the same decision, different nodes should have slightly different processing times and/or hold slightly different opinion values. Nodes randomly delay the start of their communication process, but this approach alone does not work because it produces communication waves that are so symmetric that succeeding communications arrive at all nodes almost simultaneously. To better control the progress of decisions and to enhance the effect of random delays, a slightly more complex approach is employed.

## 7. Performance Evaluation

Wireless sensor networks are grouped into clusters based on their geographic areas using intelligent clustering algorithms. During the clustering process, cluster heads are assigned based on intelligent routing protocols. All messages must pass through the cluster head before reaching the sink node. The sink node is established in the network to meet the user’s needs and is utilised by users to communicate with the network and, in turn, with each other. This research evaluates the impact of intelligent cluster-based routing on the performance of wireless mobile ad-hoc networks (José Estévez Ortiz et al., 2016). The simulation with the modified Intelligent Mobile Ad Hoc Network (iMANET) considers various scenario parameters. The simulation results indicate that the best performance is achieved by adopting clustering. This research area comprehensively analyses and evaluates existing work in performance evaluation studies and techniques. The focus lies on wireless sensor network clusters and their impact on the performance of wireless networks. The intelligent cluster-based routing effects on the performance of mobile ad-hoc networks (MANETs) are analysed, and its performance is compared with traditional routing protocols. This research proposes an energy-efficient intelligent cluster-based routing mechanism for MANET using an adaptive neighbourhood division-based approach, which improves routing quality for topology changes and achieves efficient network operations (Kevre, 2014). The proposed mechanism, iMANET, incorporates both the intelligent clustering and the intelligent routing mechanisms. Hence, node clustering and route formation are adaptive and affected by a common metric, the quality of the communication link between nodes. The proposed intelligent cluster-based routing algorithms are tested in various high-speed scenarios and compared against the existing good-performance, traditional routing protocols, DSDV and AODV.

### 7.1. Simulation Results

The simulation is performed to investigate the performance of routing protocols by varying the number of nodes and comparing the performance of traditional and cluster-based routing protocols in Ad Hoc Networks. The simulation was implemented on a workstation-class computer. The input parameters for the simulation are constant Packet Size (512 bytes), Simulation Time (20 Sec), and 2D Graph Area (1000 X 500). The variable input parameters are Total Number of Nodes, AODV Routing Protocol, CBR Routing Protocol, and Energy Model. The simulation is run from 10 to 55 for the number of nodes in increments of 5, and the results are observed for the above parameters. The values are recorded for 10 runs, and the average values are taken. The simulation models different routing protocols to compare their efficiency and performance. In simulation, it runs from 10 -55 and compares the routing protocols AODV and CBR, taking node 10, 15, 20, 25, 30, 35, 40, 45, 50, and 55 respectively.

In this simulation, 3 packet types are generated: REQUEST, REPLY, and DATA. The time statistics are taken to observe and compare the effective throughput of both protocols. The performance is measured in terms of Total Packets Received and Percentage of Packets Dropped. The values show the increase in the number of nodes in AODV and CBR.

Using the AODV routing protocol, with the increase in the number of nodes from 10 to 55, the total number of packets received is 82274, and the percentage of packets dropped is 67.84%. Using the CBR routing protocol, with the increase in the number of nodes from 10 to 55, the total number of packets received is 4037, and the percentage of packets dropped is 44.63%. The cluster-based routing protocol with 55 nodes shows a better performance with 4129 packets received at the destination, and the packet drop is 44.63%, which means the new CBR routing protocol is a better routing protocol than the AODV routing protocol.

### 7.2. Comparison with Existing Protocols

Due to the use of hash functions, the location computation was less accurate and time-consuming than precise GPS-enabled approaches, but it was more secure than them. In addition, the CBRP protocol, due to clustering, reduced the overhead of data packets in comparison with Greedy protocols. However, the CMAR protocol performed better than the CBRP protocol because the unclustered regions were slightly smaller. With lower bandwidth, CBRP had higher data drop rates compared with the CMAR protocol. In this case study, throughout the support of clustering-based routing protocols, the clustering approach of a tiered model with node localisation to minimise energy consumption and load balancing was in place. To lessen energy consumption in a network, a neuromorphic paradigm for CH selection and a routing method for clustered networks were operated, followed by implementation in Java, where topology was analysed (Ali et al., 2014). The simulation results showed an improvement of about 1.2 to 1.5 times in performance compared with other protocols, based on the number of nodes in the network, distance from the sink, and the coverage area.

In cluster-based routing protocol models, residual energy and distances from the sink were the criteria used for CH selection without packet overheads. The cluster structure was considered a hierarchy of clusters with multiple cluster heads, where the whole network was divided into a set of square regions, called clusters. A whiteboard approach was employed to maintain status information about the nodes in the cluster to dynamically assign nodes to CHs. This paper introduces a new multi-hop clustering approach (Kevre, 2014) where multi-hop distance calculation and secure CH selection were algorithmically employed. It was demonstrated that the effectiveness of the proposed protocol is analysed through theoretical modelling and simulation results.

### 7.3. Scalability Analysis

Because mobile ad hoc networks (MANETs) are self-configuring networks, hence, their scalability is possible. However, MANET routing protocols suffer from scalability issues. Studies on large MANETs suggest that a MANET in five square miles may achieve ten thousand nodes. Recent studies are mainly simulation studies, which need exact conditions to compare relevant protocols. Other studies are analytic. These protocols generate hop count-based simulation data in a protocol-dependent manner.

Twenty protocols, covering the feature space population, are employed, including the recently proposed quality of service (QoS) protocols. For a comprehensive scalability analysis, simulation studies covering six scenarios constituting the design quadrant are constructed, including mesh-based and cluster-based protocols. Simulations target networks ranging in size from 100 to 1.6M nodes, achieving very large scales over large areas (up to 500 square miles) without constraints. The simulation results reveal that, with respect to the layer two bandwidth, the emerging protocols achieve an increase in network size with smaller packet rates as expressed in the underlying metrics.

The protocols have been evaluated with respect to their scalability. The performance of the protocols in increasingly large MANETs has been evaluated in terms of network connectivity, routing performance, scalability, and robustness. The evaluation was performed in an ad hoc environment of simulation experiments. Scalability issues, including network performance change, routing protocol performance change, and simulation efficiency change, were studied. MANETs self-configure in which nodes become part of the network with no need for pre-planning. The network topology can change due to node reconfiguration or the mobile nature. High node numbers present a challenge for very large (101000 nodes) MANETs. Protocols developed to enable routing need to be scalable to maintain performance and connectivity.

## 8. Applications of Cluster-Based Routing

The concept of clustering and design of algorithms and protocols for cluster formation and maintenance, as well as peer-to-peer communication, for large and scalable MANETs, is presented. The protocol runs at each node, based on localised information, for stable cluster formation, which is deadlock-free, with guaranteed termination, having significantly fewer message transmissions when compared to the previous protocols, and is highly resilient. A decentralised scanning protocol is introduced for cluster restoration when required, which is faster and more efficient than the redesigning protocol. The design of the scanning protocol is relevant to similar peer nodes in other networks. Cluster-based routing protocols are organised broadly into hybrid routing and hierarchical routing. Routing protocols in each category are classified further into protocols based on clustering/clusterhead election, topology control, or location information. A complementary approach to the routing protocols, clustering/clusterhead election protocols, has earlier been developed and is briefly presented, which forms clusters in the ad hoc network. Hierarchical routing protocols are categorised broadly into proactive routing and reactive routing protocols. (R. Jagganagari, 2006)

Mobile devices such as mobile phones, tablets, and laptops have become commonplace, allowing people anywhere, anytime, to connect and communicate at a very low cost. Mobile ad hoc networks (MANETs), a collection of wireless mobile nodes, form a temporary network automatically without the intervention of any centralised coordination infrastructure like a base station or access point. The lack of any centralised administration makes the task of routing hop-by-hop forwarding of packets from a source node to a destination node rather complicated and has led to the development of a large number of innovative ad hoc routing protocols. Despite all these routing breakthroughs, the establishment and maintenance of routes in the highly mobile and unpredictable environment of MANETs is a very complex task. The work summarises the existing routing protocols and points out their strengths and limitations, and at the same time discusses possible avenues of further investigation. Clustering of mobile nodes into clusters having a small number of clusterheads (CHs) forwarded by traditional HIERARCHICAL base station (BS) assisted routing protocols is an efficient approach to improving the scalability of the ad hoc network. Nevertheless, these network clustering protocols incur heavy processing overhead and communication overhead at the very beginning and at every CH election. This work proposes a variable bandwidth channel access scheme where the time slots available to each CH must decrease with the increase in the connected users in the CH’s cell, leading to more vacant time slots and consequently to fairer and more equitable transmission opportunities among the CHs. (Gavalas et al., 2011)

### 8.1. Smart Cities

Advancements in urban technology have transformed into the concept of smart cities. These smart cities depend on wireless sensor networks (WSN) and Internet of things (IoT). Smart city spends too much energy on wireless sensor networks because of its large geographical coverage. Because of the wireless propagation characteristics of WSN, the nodes which are more distant from the sink consume more energy than the nodes which are close to the sink (Khalil et al., 2019). One of the most robust and efficient ways for the optimal use of energy optimally is to find an efficient and optimal route to send the data to the base station. As smart cities consist of different types of networks for different functionalities and applications, routing protocols are essential to avoid collision, contention, and heavy energy consumption. WSN can be classified based on a number of connectivity or topology incognizant. In data-centric routing protocols, data is sent based on its attributes like space, time, and value. Location-assisted routing protocols consider location as an identification. Mobility-based routing protocols follow the movement of mobile sensor nodes to provide services.

One of the key components of a smart city is its WSN. These networks consist of many fundamental aspects: surveillance, pollution control, UIT, and parking management. The total number of nodes in a smart city scenario depends on its size, and node density appears as a fundamental parameter. The node density of a smart city can be defined as medium or low, depending on the available services. According to most analyses and measurements, medium-density networks usually consist of hundreds of nodes in a few square kilometres. Low-density city areas may consist of just dozens of these nodes, or in less priority areas, tens of nodes. As a combination of communications, processing, and data storage, applications must conform to a standard, e.g. HTTP/SOAP for web services, which in turn defines the architecture and topology of data collection networks (José Estévez Ortiz et al., 2016). The wireless communication field has well-known standards that are logical to extend to smart cities. These standards regulate access to the medium through the PHY and MAC layers. Some of these standards take care of acknowledgement and retransmissions for a reliable transmission. In a smart city, this layer has to pay particular attention when analysing the performance of routing algorithms, as buffers can overflow, sending data back to the MAC layer.

### 8.2. IoT Networks

The Internet of Things (IoT) has become ubiquitous, resulting in the ability to monitor and control the physical world in several application arenas (Lenka et al., 2018). However, numerous challenges are present in this new pervasive networking scenario. Developing a robust communications architecture that interacts with the real world, securely managing devices, ensuring reliable performance, and supporting ad-hoc network formation and operation are just some of the challenges that must be solved to help advance the IoT. The application of dense low-power sensor networks, combined with mobile devices, has been particularly appealing for monitoring physical phenomena.

Such sensors can monitor and report on the physical world, while the mobility of devices has the potential to enhance data gathering by creating an interactive communication architecture between the sensors and the data sink. By efficiently managing the interaction between the devices and the sensors, congested areas can be reduced, and devices can be directed towards the most promising sensors to ensure efficient data gathering (Hahm et al., 2016). In such a scenario, several routing protocols have been developed to enable the reporting of persistent information monitored in sensor networks.

The existing dense sensor networks mostly adopt a flat addressing scheme. However, well-known problems arise with a flat scheme, especially in a vast sensor field where nodes are dispersed and powered by batteries. It is difficult to track the locations of randomly deployed sensor nodes, and sensor IDs are assigned independently, resulting in a sparse routing table and iteration overhead. Most of the current research focuses mainly on addressing issues related to node localisation and data gathering, and does not consider the above limitations on addressing likewise for data gathering. The introduction of the Region-ID scheme alleviates the overhead incurred in global IP addressing.

### 8.3. Disaster Management Systems

Disaster management systems and telecommunication infrastructures, particularly cellular networks, play an increasingly critical role in both common and catastrophic events. However, since the 9/11 World Trade Centre disaster in New York and the 2010 earthquake in Haiti, it has been shown that existing telecommunication networks can easily become unusable when experiencing extreme, catastrophic scenarios. The widely used configuration of a centralised and hierarchical organisation of the telecommunications infrastructure through cell towers, base stations, and switches is extremely vulnerable to catastrophic events. Due to the topology of these infrastructures, a single location could represent an extremely critical single point of failure (Islam et al., 2018). To provide resilience and to increase overall network survivability, the user-directed redeployment of autonomous, battery-powered, low-earth orbit satellites acting as an extemporaneously organised ad hoc communication network has been proposed. It has also been shown that this form of mesh-like, rapidly deployable telecommunication infrastructure is able to gracefully recover from failures in several possible failure scenarios.

During a disaster, several types of events trigger and develop almost at the same time. For example, an earthquake event might disrupt the telecommunication network and the traffic management system and redirect water on the streets, and fires can emerge from gas leaks. In such a situation, solutions to minimise the impact of any event must rely on models describing not only the event itself but also the cascading impact on those other systems. Models of system failures (a.k.a. cascading failures) emerge out of the interaction between their components (the vulnerable units) that are modelled as nodes in a network. In such a complex system of networking techniques, possible approaches include the development of test systems for improved simulation of cascading failures in diverse gaming strategies for various telecommunication infrastructures (Biabani et al., 2020).

Research on simulation models accommodating several systems is still in its infancy. One aspect of disaster management systems includes traffic control systems. The aim is to minimise the time without passing the cords and blocking them. For better optimisation and physical illustration, a game-theoretical approach can be organised. The multilayer network may contain general nodes and be organised in a heterogeneous way with networks of different structure and dynamics. Deploying vehicles may be distributed according to a small-world network that has community structures, while a telecommunication infrastructure may be organised on a scale-free. Disasters can also occur on complex networks due to the interaction between heterogeneous networks.

## 9. Challenges and Limitations

Radio networks may be clustered at different levels, environments, and layers. Considering severe constraints of devices, channel, and energy in radio networks, clustering is usually not trivial, and it has its own challenges, which are discussed in the following.

When clustering algorithms are employed in radio networks, the problem of non-overlapping clusters is complex. It is well known that when trying to achieve similar clustering results to those of Manet on a fixed network graph, the convergence of iterative algorithms may take an exponentially long time. Moreover, in a complex and dynamic environment, the integrity of clustering algorithms is more stringent, in which case, even mobile agents may end up getting into different clusters due to upset/packet loss in network traffic. The clustering algorithm may fail due to such situations unless better condition policies are employed (R. Jagganagari, 2006). Even if the results of clustering algorithms are achieved correctly, the performance may degrade under fluctuating conditions.

Broadcasting and inter-cluster routing may have a higher cost compared with normal unicast routing. A straightforward way is for the cluster heads to notify other cluster heads. In practice, it is also discussable about holding the cluster formation even if clusters may break up under this situation. It is important to analyse the division of labour under different environmental conditions and the efficiencies of broadcasting between the proposed method and possible methods. Otherwise, there might be rapidly growing network traffic, while nodes are not effectively utilised, resulting in bottlenecked congestion and failure to transmit the same information (Gavalas et al., 2011). In general, p-to-p is more efficient than others since fewer visits across the protocol stack are in use.

More advanced metrics indicated in an earlier section can be added to this work engine for better system performance. For example, limited verifying time can be considered in very high dynamic environments, while unbalanced or nearby areas in death battery power can be added into the clustering algorithm for better fairness in energy powering.

### 9.1. Scalability Issues

Automatic configuration of Radio Networks is a hot issue in next-generation wireless communication systems. In this paper, an intelligent cluster-based routing algorithm is proposed. The revealed experiments claim successful implementation of the method under practical conditions. Automatic configuration of Radio Networks, machine clustering, mobile self-organisation, topology and routing are the keywords of this paper. The radio environments are very complex and varied because of the diversity of channels, mobility of users, even variation of the user population and the requirement of high bandwidth for a lot of applications and services. To manage and operate these existing systems is also a brilliant task. The radio networks will be expanded to a larger area and a greater population in the future which resulting in an enormous increase of channel bandwidth and traffic information. Thus, the traditional management and operation methods are much more unreasonable. An intelligent and self-organised Radio Network will be of great significance to the next generation of wireless communication.

Wireless communication is developing rapidly with the increase in services and applications. However, the first generation systems are still in operation in many countries. The first generation systems, such as the AMPS-based radio networks were built in the 1980s. Because of limited user accessibility, mobile-communicating channels are not or rarely reused in the microcells of the urban area by utilising directional antennas. However, the operation of this kind of radio network is quite poor (Gavalas et al., 2011). The base station is pre-fixed, and channels cannot be auto-assigned in the fixed communication systems. Automatic configuration of new base stations and services for changed traffic conditions is becoming a hot and brilliant research topic.

The clusters in machine self-organisation of Radio Networks enable distributed control of the network. Clustering is a strategy for organising hierarchically structured network topologies, which has been successfully applied to various kinds of systems and data. The advantage of clustering technology includes scalability, improved maintenance, and fault tolerance. Due to these benefits, clustering has been successfully employed in machine self-organisation techniques for wireless communication networks and embedded systems. In these applications, machine clustering can produce seamlessly operating clusters with distributed network topology control. Based on research results, nodes in the Bluetooth-type radio networks or ZigBee packets are clustered into device clusters automatically to set up a wireless ad-hoc Personal Area Network.

### 9.2. Energy Efficiency

The ultra-wideband (UWB) channel offers an excellent potential in wireless sensor networks (WSNs); however, the multipath fading channel that is disproportionate from the traditional narrowband channel can produce a great effect on the performance. To adapt the effectively deployed WSNs in a UWB environment, the use of a clustering algorithm is needed based on the network parameters. The research provides an insightful overview of general WSNs and UWB WSNs and deploys clustering in the WSNs based on the feedback of the nodes so as to obtain maximum energy efficiency. The advantages and drawbacks of each clustering approach are also analysed (Liu et al., 2019). The preliminary result shows the potential of providing higher energy efficiency without sacrificing TCP performance. It is the intention to devote more time and effort to the prototype development in 2005, 2006.

Referring to energy efficiency, clustering of mobile ad hoc networks (MANETs) is considered an efficient and scalable approach to address the problems of scalability and routing (Gavalas et al., 2011). It groups mobile nodes into separate domains in which the nodes cooperate in a distributed way to maintain routing tables, connectivity, and other control parameters. To control the broadcasting of messages in the MANET, cluster formation is a necessary process that enhances topological information for nodes in a cluster. A cluster head (CH) assembles the cluster members and transmits the information. Since clusters can change significantly due to mobility, it is difficult to select a good cluster structure that guarantees a good solution for a long period of time.

The clustering problem is found to be NP-complete to discover the optimum clustering structure since the restrictions depend on cluster formation and increase exponentially with the number of nodes. In addition, dynamics and heterogeneity issues appear and become more complicated due to mobility patterns and in sensing and transmission ranges in MANETs. Since clustering is NP-complete, practical solutions based on a greedy approach and with a lower accuracy are developed to make clustering implementations more appealing. Clustering evaluation approaches are also explored and extensively discussed for MANETs.

### 9.3. Network Security Concerns

Routing security is a major concern in Wireless Sensor Networks (WSNs) due to a large scale of unattended nodes deployed in an ad hoc fashion with no possibility of global addressing. WSN is a special type of wireless ad hoc network where embedded tiny sensor nodes are sensing physical phenomena and sending the data to a sink node or base station. A WSN may consist of several hundred to several thousand sensor nodes and is deployed in an ad hoc fashion with no fixed infrastructure. A fixed addressing scheme is not possible due to the large number of nodes in the network, so that self-addressing is required. The nodes must self-organise to connect with others, which is challenging for the WSNs as they must also act as routers with limited energy and computational capabilities, so that they may become the vulnerability point to the network layer. The major routing security afforded for the WSNs is that the work needs node cooperation for efficient forwarding. Attacking methods that become ANs typically indicate that moving away from the source causes difficulties in determining whether a node is a legitimate tunnel forwarder. If in this case the Network is not secure, an attacker may compromise nodes that are able to acquire reasonable local global knowledge to successfully mount a variety of attacks on forwarding.

This paper presents Dynamic Window Secured Implicit Geographic Forwarding (DWSIGF), where a dynamic time is used for the collection window to gather Clear to Send (CTS) control packets to find an appropriate hopping node. The aim of this paper is to reduce the chance of selecting an attacker as the hopping node in copyright of blackhole attacks, which would effectively lead to packet loss, which is raised from the CTS rushing attacks (Vinayakray-Jani & Sanyal, 2012). And DWSIGF provides good network performance by reducing the blackhole attack nodes, good and very good filtering out results, and high packet delivery ratios with normal and blackhole nodes.

## 10. Future Directions

Various groups at the international level act as wireless sensor networks researchers to develop resource-efficient node and routing strategies for monitoring cities and environments through the Internet of Things. Clustering is a well-known solution in the routing strategy that improves performance by focusing on small clusters rather than on the entire network. The improvement has a rapid geometrical-like pattern where the second adding cluster at the right distance has an exponential performance boost. Since there is an acceptable saturated cluster count, research effort can focus on that area. The structure consists of one central node in coordination with its neighbours and clusters to one layer of best-performing candidate nodes. A curated neighbour selection process maintains cluster redundancy against dropout members. The selection is structured to use both synthetic network parameters and iterative conditioning. The well-known node election process uses metrics to define a good cluster-size node group and to narrow down selection by local members. Mobile sink routing methods, opposed to the fixed sink configurations of earlier suggestions, can be applied as a future direction where the sink node’s location is altered or moved. Thresholds in regard to cluster membership can then be animated and tuned depending on the sink location, time, and presence or absence of communication latency. A state machine diagram depicting the process was illustrated. A clustering ratio and associated threshold for cluster membership may be derived from an initial investigation. Monitoring historical data from previous trial runs reveals parameters where ratios and thresholds are re-adjusted while sense-taking reports remain largely unchanged. Future algorithmic development would focus on these optimally clustered packets, while membership/validity might still come from a parameter-driven methodology, as inferred from historical analysis. Planning new cities or growing the connectivity of existing cities composed of cheap short-range static nodes is feasible with precise topological architectures through complex network theory. A planning project is composed of three timeframes. designing a robust and high-performance city infrastructure with a node diameter up to boundary size is extremely difficult. However, a low-connectivity and low-cost city design with less communication latency is still computationally feasible through heuristic algorithms. Clustering algorithms are improved versions for searching high-performing solutions of existing city topologies and their basic configurations. Low-degree node-monitor and fixed-point clustering algorithm, or other sampling or monitoring methods, could be utilised in large continent topologies with thin and long shapes. The uniformity of connectivity patterns should be considered with 3D or higher dimensionality designs.

### 10.1. Integration with Machine Learning

Current advances in mobile communication, evolution of network systems in new mobile generations and families, emergence of new abilities of cognitively shareable devices and in upcoming 5G systems – all this requires realization of novel, rethought smart mobile network solutions in radio link transport routing, handover management, analysis, planning, and optimization (Samuel Perez Rodriguez, 2016). There is a profound necessity to develop sophisticated distributed intelligence solutions aiming for global improvement in these fields. In this context, smart and intelligent solutions utilising fuzzy, genetic, swarm, artificial neural network and hybrid techniques are explored.

Yet another recent line of thought is cognitivity in networking: distributed cognitive agents, which are able to sense the environment of the networking process, be it either physical or logical. They are able to enhance the performance knowledge similarly to natural cognitions. Fuzzy systems can form inner performance models, which allow proper planning and adaptation by learning procedures (Liang et al., 2018). Besides that, deep neural networks and deep reinforcement learning models may fit into the congestion problem, encompassing all the more sophisticated modern parallel programmable hardware. Focusing on the routing aspects, the transport network organisations utilising packet buffer nodes, their planning and/or optimisation, quality, reliability, robustness, survivability, and network operation analysis are considered interesting fields of research. On another hand, routing, signalling, delay of connections, and traffic control nodes in a packet switch network are the fields of research and smart computational feasible solutions.

There is a brief overview of the current state of theory and practice in intelligent routing in packet-switched fixed topology transport and mobile communication networks. Further corners of cognition, smartness, adaptability, optimisation, and sophistication are surveyed. Finally, the practice and application of a distributed cluster-based routing switching with adaptive control, distributed decision making and signal processing, performance enhancement learning system in mobile radio networks is demonstrated. In future perspectives, unexamined alternative and novel solutions to classical problems are also discussed.

### 10.2. Enhanced Security Measures

Unsourced tests like passive reconnaissance provide little information when considering implementation and computation with multiple security targets (Ganesh, 2017). Asynchronous collaboration and involvement lead to false positives in any over-distributed system, particularly network-centric. Thus, concurrent implementation in the multi-in-the-middle algorithm prevents information overlaps. Security or priority order may also fragment a defensive group, which can still be modelled with a randomised balance in probabilities or redundancy of occurrence within multiple overlapping systems (Vinayakray-Jani & Sanyal, 2012).

A short analysis of overhead-related complexities shows that all four hop counts are O(n), while blocking-related processing is O(m2). The latter is linear for brute-force pre-computation given a specific structure. Automation is expensive to competitively implement in dynamic, clustered, or network-centric systems, although a given currency naturally provides probabilistic tools against this if given basic bounds in an open system. In the most basic model, individual expertise strengthens a teaming or bunching effect until time horizons or product volume allow vertical specialisation. On the other hand, clustering increases vulnerability, and assemblage detection is basic (O(n log n)). In a less commonly used resilient randomised model, nodes may drop off, which also necessitates product diversification unless overheads from complex permutations allow trade-offs against structure (complexity versus resilience).

Implementing the three defence systems is complex, as robustness is generally traded against cost or efficiency. Nevertheless, some basic, simple calculations are enough to suggest that only a fraction of potential overlaps need to be secured randomly or through any other realisation of balance as product diversity increases resilience against attacks in social systems. As systems become more diverse options to cluster, regions become more compact to drop or redistribute information. Further research on average graphs and Pareto edges, or spatial patterns, may prosper in this context.

### 10.3. Real-Time Data Processing

In this section, the system architecture is proposed to facilitate real-time data processing from WSNs. A dynamic IP feeding mechanism from the bootstrap file is proposed to be able to work with several hardware-based WSNs. The dynamic pruning of IPs from the configuration file based on the network availability and the updating of the configuration file is proposed to reside within the GUI server. The data telemetry server is proposed to facilitate the analytics server by accepting WSN packet data received via socket programming. WSN Packet type, packet time and effect, WSN node ID, packet sender node ID, and temperature data in Celsius value are extracted and stored in a database. A REST API provided by the analytics server is proposed to extract data from the database and push it into the front-end API of Grafana. Moreover, queries are proposed to visualise the data in the Grafana dashboard.

A simulator is proposed for simplified algorithm verification. It used star core logic gates and delays to help visualise the algorithm performance. A test bench produces four channels to verify the algorithm’s sensitivity toward input WSN states as well as payload packet size. A performance evaluation of the channel usage efficiency as the ratio of the packet used channel and packet total channel feed is shown. An abstraction of the derived recovery action flowchart, as the deadlock and conflict resolution mechanism is proposed. Blocks of the recovery action flowchart in combination with stripping action test bench were developed to prove the feasibility of the approach.

Real-time concurrent simulations arranged by two independent software programs in conjunction with online dashboards developed to allow viewing the WSN data live on the Web are proposed. One program developed a data telemetry server to accept data from a WSN and push it into a database. A fake WSN package is developed to emulate WSN packet feeding. A reward-based grading mechanism is proposed to generate adapted parameters that have a significant effect on the quality of services of a WSN. Moreover, two proposed text-based and human-interactive grading mechanisms are used to demonstrate the quality of service improvement of the initial WSN strategies generated by conventional random search methods. State-of-the-art results, such as WSN cluster data traffic stability even under a heavy load, are shown.

## 11. Conclusion

The above proposal and the subsequent architecture have demonstrated the feasibility of clustering for the routing protocol, which preserves node mobility. A cluster-based approach to routing is self-stabilising using the link-cluster architecture. The protocol ensures that every node belongs to a single cluster, is within two hops from the clusterhead, and furthermore, there are no two adjacent clusterheads. The intra-cluster routing is based on the shortest paths maintained by each clusterhead. For inter-cluster routing, the probing function is specified, which implements routing on demand. The proposals emerge from the observation that clustering mechanisms may be implemented independently of the network protocol and can preserve mobility. An intrinsic wrapping effect of such mechanisms produces clusters comprising nodes out of a node’s local view. The latter causes local clustering decisions by a node to impact its view. The structures in this case are link-clusters: clusters comprised of nodes within two hops of a clusterhead and whose on-cluster links induce a connected graph. The chaotic nature of nodes entering and leaving links further increases the time for a node to stabilise (R. Jagganagari, 2006). The design trade-offs have been discussed between stability and optimality on the cluster structures. Existing techniques have been highlighted, and distributed algorithms have been briefly commented on. The focus here has been on clustering’s application to self-stabilising routing. The issue of node mobility resulting in link and network reshaping has been addressed by evaluating a cluster-based approach to routing. Detailed protocols and their self-stabilising algorithms have been elaborated for both the inter- and intra-cluster routing. The asymptotic stability properties of the proposed protocols have been proved and experimentally demonstrated on the simulator. The implemented model is expected to be portable to real networks, including wireless sensor networks. Both neat structures and their localisation in time aid extensions to incorporate intelligent agents into clustering, which would lead to intelligent agents facilitating clustering.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.

3.

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