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An Efficient and Interference A Ware Multihop in Submarine Sensor Network

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Abstract:
Submarine phonic conversation is a technique of sending and receiving message below water. There are several ways of employing such communication but the most common is using hydrophones. Submarine communication is difficult due to factors like multi-path propagation, time variations of the channel, small available bandwidth and strong signal attenuation, especially over long ranges. In submarine conversation there are low data rates compared to physical conversation, since submarine conversation uses phonic waves instead of electromagnetic waves. In the existing approach, the data can be collected from the sensor node and transfer the data to the target. The same origin information can be send through multiple paths through the same target. So the packet bit error rate is high and power and energy consumption for transferring data is high. In the submarine sensor network, the main problem is the energy consumption. The bandwidth and the energy can be consumed. And then the packet bit rate is the serious problem in the existing system. It can be overcome by using the segment combination in the hamming code technique. The packet bit rate can be overcome by increasing the number of paths. The number of paths can be increased based on calculating the cost. For calculating the cost, least cost algorithm is used. And based on the minimum cost path, the path is chosen and data is transferred to the same target.

Keywords: Submarine Sensor Networks, Packet Error Rate, Forward error correction.

I. INTRODUCTION

Recent advances in networking technologies and phonic transmissions have enabled the deployment of Submarine Sensor Networks (USNs) for a variety of attractive applications, such as oceanographic data collection, pollution monitoring, offshore exploration, and military surveillance. However, the high Packet Error Rate (PER), long channel latency, and low bandwidth are the inherent issues in USNs characterized by the phonic channels. Moreover, the feature of low energy efficiency brings fundamental challenges in design of USNs. Hence, this unique characteristic motivates the research community of USNs to seek a reliable, scalable, robust, and energy-efficient approach for design and deployment of USNs. This paper attempts to address this issue by 1) integrating the Hamming Coding-based Forward Error Correction (FEC) scheme with multipath transmissions (MPC), 2) designing a novel packet recover technology based on segment combinations for the FEC scheme, and 3) designing a Decision and Feedback scheme for multipath transmissions. USNs have attracted many research efforts from academy and industry. In industrial fields, LinkQuest, Inc., a leading manufacturer of precise phonic instruments, has developed a series of dominant products, Submarine Phonic Modems (UWMs), which can achieve 10^{-9}, -10^{-7} Bit Error Rate (BER). However, the transmit model power is in the range of 1-40 W and the devices are heavy and expensive. As a result, they are not suitable for deploying large-scale USNs. In order to forge the links with industrial fields, in academic fields, several mechanisms have been proposed to improve the performance of USNs in terms of energy efficiency, reliability, robustness, and scalability. Furthermore, existing studies (e.g., [1]) have shown that the PER in the extremely unreliable area can be substantially low if the FEC scheme is employed. Xie and Cui [2] proposed a segmented data reliable transport (SDRT) protocol to achieve reliable data transfer in USNs. However, SDRT may cause much long delay because Tornado code requires more redundant blocks and thus SDRT is not utilized in the multipath transmission.

The traditional bit-voting-based packet combination scheme [4] in the target node splits the packets received from multiple paths into multiple bits and then votes the bits, thus ruining the integrality of the segment in packets because the segment should be decoded as a whole unit instead of bit-to-bit if the FEC scheme is handled in the network node. As a result, the successful probability of packet recovery for the bit- based majority voting scheme is not high, and it consumes more energy because the number of the multiple paths is the key factor of determining energy efficiency in the multipath wireless communication.

II. RELATED WORK

In the paper [1] "A Survey of Practical Issues in Submarine Networks," the authors J. Partan, J. Kurose, and B. Levine, stated that submarine sensor networks are attracting increasing interest from researchers in physical radio-based sensor networks. There are important physical, technological, and economic differences between physical and submarine sensor networks. Previous surveys have provided thorough background material in submarine transmissions, and an introduction to submarine networks. This has included detail on the physical characteristics of the channel [2], on submarine phonic transmissions [3, 4, 5], and surveys of submarine phonic networks [6, 7, 8, 9].

In this survey, it highlight a number of important practical issues that are not emphasized in the recent surveys of submarine networks, with an intended audience of researchers who are moving from radio- based physical networks into submarine networks. It focus on issues relevant to medium access control (MAC) protocols, which are an area of continuing work both in physical sensor networks and especially in submarine networks. Submarine networks are often characterized by more expensive equipment, higher mobility, sparser deployments, and different energy regimes when compared with physical sensor networks.

It discusses the role of these factors in the different set of challenges that face submarine networks. It provides a classification scheme for submarine networks. Link-layer range, node density, and geographic coverage of nodes are key factors in determining the type of network deployed. The key differentiating factor for submarine networks is the use of an phonic channel. It reviews the basics of such channels. It also mention results from submarine optical and radio transmission systems, explain the half-duplex nature of the channel, and discuss the impact of the physical layer on network topology. Another important issue is the interaction between transmission and navigation signals, which often share the same physical channel.

The energy costs in submarine phonic networks are different from those in physical radio-based networks. In phonic networks transmit power dominates compared with receive power. Protocols that optimize energy usage need to be evaluated with this in mind. In addition, in mobile submarine networks with high propulsion energy costs, minimizing network transmission energy is not always an important concern. Thus, protocol designers may want to consider alternate metrics, such as reliability, fairness, quality-of-service, or covertness.

Submarine Network Operating Regimes

Submarine networks can be characterized by their spatial coverage and by the density of nodes. These factors have significant implications for the MAC- and network-layer issues that must be addressed at design time. In this section, it creates taxonomy of submarine network operating regimes with the goal of providing context for the discussion later in this paper. It characterizes the spatial extent of a network by comparing it to the phonic range of the nodes. If all nodes are in direct contact, it has a single-hop network, with either centralized or distributed control. In networks covering larger areas, transmissions will require multiple hops to reach targets. When the geographic coverage is greater than the unpartitioned link-layer coverage of all nodes, routing requires techniques from disruption-tolerant networking (DTN). When even the mobility of nodes does not overlap, no techniques exist to form a network.

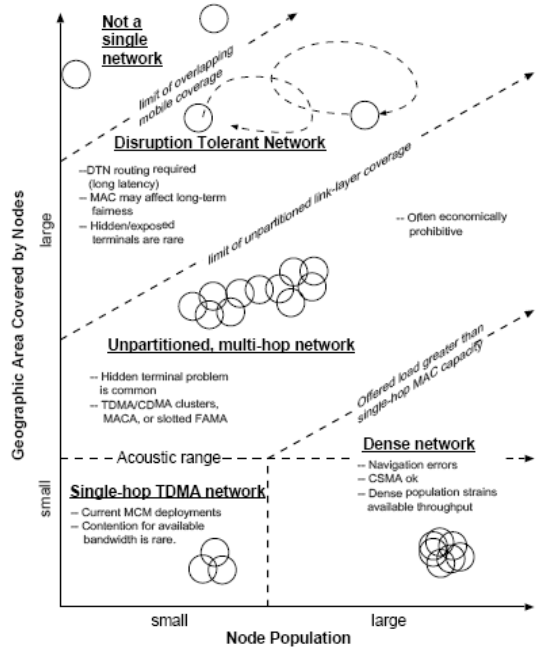

Figure.1. A Taxonomy of Submarine Networking regimes

There are several additional differences of note between physical radio-based networks and submarine phonic sensor networks. One is that large populations of nodes in small areas can cause conflicts with throughput and navigation. A second point is that densely populating a large geographic area can be simply prohibitively expensive. In practice, all of the network types shown in Figure 2.1 are relevant and can exist within an extended network. In other words, clusters of single- or multi-hop networks can be deployed that use DTN routing to exchange information infrequently.

PHYSICAL CHANNEL:

Almost all submarine transmission uses phonics. Radio waves are extremely strongly attenuated in salt water [10]. Long-wave radio, however, can be utilized for short distances; for example, 1–8kbits/sec at 122kHz carrier for ranges up to 6–10m [10]. Light is strongly scattered and absorbed submarine, though blue-green wavelengths may be utilized for short-range, high-bandwidth connections in extremely clear (often very deep) water. In very clear water, optical modems are expected to achieve data rates up to several Mbits/sec at ranges up to 100m [11]. Submarine optical transmission is also being considered for very low-cost, short-range connections of order 1–2m at standard IrDA rates such as 57.6kbits/sec [10, 12]. For longer ranges and more typical water clarity, phonic transmission is the only practical method. A rough performance limit for current phonic transmissions is the limit of 40 km· kbps for the range-rate product, though this mostly applies to vertical channels in deep water, and it dramatically overestimates the performance in difficult shallow- water, horizontal channels [3]. The speed of sound submarine is approximately 1500 m/s, 2e5 times lower than the speed of light. This leads to large propagation delays and relatively large motion-induced Doppler effects. In the paper [13] "Pressure Routing for Submarine Sensor Networks," the authors U. Lee, P. Wang, Y. Noh, L.F.M. Vieira, M. Gerla, and J.-H. Cui, stated that A SEA Swarm (Sensor Equipped Aquatic Swarm) is a sensor *cloud* that drifts with water currents and enables 4D (space and time) monitoring of local submarine events such as contaminants, marine life and intruders. The swarm is escorted at the surface by drifting sonobuoys that collect the data from submarine sensors via phonic modems and report it in realtime via radio to a monitoring center. The proposed routing protocols are validated via extensive simulations. Submarine sensor networks were recently proposed to support time-critical aquatic applications such as submarine tracking and harbor monitoring [14], [15]. Unlike traditional tethered sensors, a large number of submarine mobile sensor nodes are dropped to the venue of interest to form a SEA Swarm (Sensor Equipped Aquatic Swarm) that moves as a group with water current [16], [17]. Each sensor is equipped with a low bandwidth phonic modem and with various sensors (e.g., Drogues [18]). Moreover, it can control its depth through a fish- like bladder apparatus and a pressure gauge. The swarm is escorted by sonobuoys at the sea surface that are equipped with both phonic and radio (e.g., WiFi or Satellites) transmissions and GPS (See Figure 2.2).

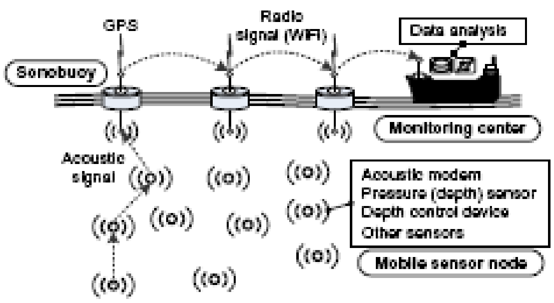

Figure .2.2 Sea Swarm Architecture

There are several major advantages of SEA swarm architecture. First, mobile sensors provide 4D (space and time) monitoring, thus forming dynamic monitoring coverage. Second, the multitude of sensors (as in the SEA swarm) help provide extra control on redundancy and granularity. Third, floating sensors increase system re-configurability because they can control their depth; moreover they resurface once depleted of energy and can thus be recovered and reused. In the SEA swarm architecture, each sensor monitors local submarine activities and reports time- critical data to any one of the sonobuoys using phonic multi-hopping; then the data are delivered to a monitoring center using radio transmissions. The main focus of this paper is to design an efficient any cast routing protocol from a mobile sensor to any one of the sonobuoys on the sea level. However, this is challenging due to node mobility and limited reorigins (bandwidth and energy) of mobile sensors. An submarine phonic channel has low bandwidth and propagation latency five orders of magnitude higher than the radio channel [19]. Phonic transmissions consume much more energy than physical microwave transmissions. Such severe limitations in transmission bandwidth coupled with high latency and limited energy make the network vulnerable to congestion due to packet collisions. Under these circumstances, minimizing the number of packet transmissions is important for at least two reasons:
minimizing congestion and minimizing energy consumption. Conventional proactive/reactive routing protocols (e.g.,OLSR, AODV, etc.) rely on systematic flooding for route discovery and maintenance, potentially causing excessive energy consumption and collisions. In a SEA swarm scenario, general 3D geographic routing is preferable as it is stateless. However, geographic routing requires online, distributed localization of mobile sensors which is expensive and takes a long time to converge. Also, Durocher et al. [20] showed that efficient recovery from a local maximum may not always be feasible in 3D geographic routing, thus requiring an expensive exhaustive search such as 3D flooding and random walks [21]. "An Energy-Efficient Mac Protocol for Submarine Wireless Phonic Networks," the authors V. Rodoplu and M.K. Park, stated that It propose a distributed, scalable, energy-efficient MAC protocol that works despite long, unknown propagation delays of the submarine phonic medium. This protocol can be utilized for delay-tolerant applications such as submarine ecological sensor networks between energy- limited nodes. The protocol differs significantly from ALOHA, MACA, and MACAW protocols in that energy is the main performance metric in the case rather than bandwidth utilization. It is shown that under a realistic submarine sensor network scenario, our proposed MAC protocol wastes only 3 percent of the transmit energy due to collisions, when an average number of 1-hop neighbors is 5, and the duty cycle is This distributed, scalable MAC protocol has the potential to serve as a primer for the development of energy-efficient MAC protocols for future submarine sensor networks. The design of a MAC protocol is challenging for the operation of energy-limited sensor nodes in Submarine Wireless Phonic Networks (UWANs) due to energy limitations, long propagation delays, low data rates, and difficulty of time synchronization in submarine environments [30][31][32]. The aim in this paper is to develop an energy-efficient MAC protocol that will operate under large propagation delays for ecological monitoring applications. It concentrates on a rather dense network of hundreds of sensors with node spacing of up to 100 meters. Such short distances extend battery life by using low-power transmissions. In addition, it exploit the idea of "sleep mode" to save its energy with relatively low duty cycles, by focusing on an asynchronous, delay-tolerant data collection applications such as conductivity, temperature and depth (CTD) measurements. The recent design of energy-efficient MAC protocols has concentrated on physical sensor networks and the techniques that have been developed are not suitable for the challenging submarine phonic transmission medium that experiences very large propagation delays (of 1 second over 1.5 km). In past phonic network deployments, FDMA was used (e.g. in the 1998-1999 SeaWeb), but was found to be restrictive and inefficient in terms of bandwidth utilization. SeaWeb 2000 favored a CSMA/CA solution with RTS/CTS exchange; however, the problem with the CSMA/CA solution is that it exacerbates the end-to-end delays that are incurred, especially in submarine sensor networks with a large number of nodes. In addition, the authors use both the RTC/CTS handshaking and ARQ retransmission at the MAC layer to minimize data loss, which increases the energy consumption. More recently, an submarine networking solution proposed by Xie and Gibson seeks to achieve lower and more predictable end-to-end delays in the network by use of a base station that computes routes for all submarine sensors. This obviates the RTS/CTS exchange and significantly reduces both the propagation delay and jitter along each route; however, there

are issues regarding the scalability of this centralized solution to a large number of nodes. Moreover, transmission of optical signals requires high precision in pointing the narrow laser beams. Thus, links in submarine networks are usually based on phonic wireless transmissions [37]. Many researchers are currently engaged in developing networking solutions for physical wireless ad hoc and sensor networks. Although there exist many recently developed network protocols for wireless sensor networks, the unique characteristics of the submarine phonic transmission channel, such as limited bandwidth capacity and high propagation delays [38], require very efficient and reliable new data transmission protocols. Major challenges in the design of submarine phonic networks are:

1. Propagation delay is five orders of magnitude higher than in radio frequency (RF) physical channels and variable;
2. The submarine channel is severely impaired, especially due to multipath and fading problems;
3. The available bandwidth is severely limited;
4. High bit error rates and temporary losses of connectivity (shadow zones) can be experienced;
5. Submarine sensors are prone to failures because of fouling and corrosion;
6. Battery power is limited and usually batteries cannot be easily recharged, also because solar energy cannot be exploited. Most impairments of the submarine phonic channel are adequately addressed at the physical layer, by designing receivers able to deal with high bit error rates, fading, and the inter-symbol interference (ISI) caused by multipath. Conversely, characteristics such as the extremely long and variable propagation delays are better addressed at higher layers. For example, the delay variance in horizontal phonic links is generally larger than in vertical links due to multipath [24].

III. PROPOSED METHODOLOGY HAMMING CODING

When retransmissions are relatively costly or impossible, FEC becomes a suitable way for provisioning of reliable data transmissions. In FEC, redundant data, also known as an error-correction code, is added to packets before transmission. The purpose is to allow the receiver to detect and correct errors without asking the sender for retransmission. FEC codes can be classified into two main categories: block codes and convolution codes. Hamming Coding belongs to the former, which can correct single-bit errors and makes it possible to provide reliable transmission. Specifically, 7-4 Hamming Coding contains 4- bit origin codes and 3-bit error-correction codes in each 7-bit segment. The 7-bit segment, ^ S, is obtained from the 4-bit origin codes, S, following the linear operation:

$$\hat{S} = SG,$$

where G is the generator matrix of the code for 7-4 Hamming Coding. At the receiver side, the decoding process is to check which bit encounters error according to the encoding principle so as to correct the error bit.

BIT-BASED PACKET COMBINATION

Generally, in multiple-path transmissions, after the target node receives all the copies of the original packet from multiple paths, it will combine these copies using bitbased majority voting scheme. Suppose there are l copies of the original packet received in the target node, the ith bit, bi, in the final combined packet is determined by

$$b_i = \begin{cases} 1 & \sum_{w=1}^{l} b_{iw} \geq l/2 \\ 0 & \sum_{w=1}^{l} b_{iw} < l/2, \end{cases}$$

where biw is the ith bit in the wth, ð1 _ w _ lÞ, packet. As a result, the final packet can be combined bit by bit.

BIT-BASED VERSUS SEGMENT-BASED PACKET COMBINATION APPROACHES

The inherent characteristics of phonic channels in USNs including the low bandwidth, high latency, and high BER pose many challenges in provisioning of reliable submarine transmissions. Without any error correction scheme, it is impossible to provide low BER transmission in the extremely unreliable area. Thus, FEC based on the Hamming Coding scheme is a useful approach to improving BER. Furthermore, the crucial performance in terms of energy efficiency is taken into account for designing USNs. However, energy efficiency and delay are paradox typically in wireless networks. To bridge this gap, a widely used scheme, energy-efficient multipath transmission has been proposed to eliminate retransmission and reduce delay. MPC is utilized from the same origin node to transmit the same packet along multiple paths to the target node where these corrupted packets are combined bit-to-bit using the majority voting scheme as to recover the original packet. In order to investigate the impact of diverse packet combination schemes on the number of multiple paths required for error correction in FEC,

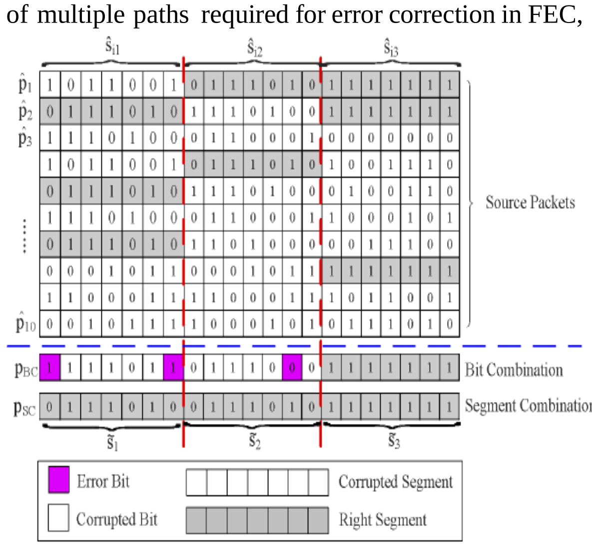

Figure .3. Comparison of Bit-Based and Segment Based Combination

VI. NETWORK ARCHITECTURE

It has been verified that the multiple-path transmission is high efficient and feasible in the deep submarine area. Multipath routing has drawn extensive attention in the research community of wireless sensor networks. The dense node deployment makes multipath routing a natural and promising technique to cope with the unreliable network environments and large end-to- end packet delays. Thus, multipath transmission enables to improve the robustness and reduce end-top- end delays for USNs.

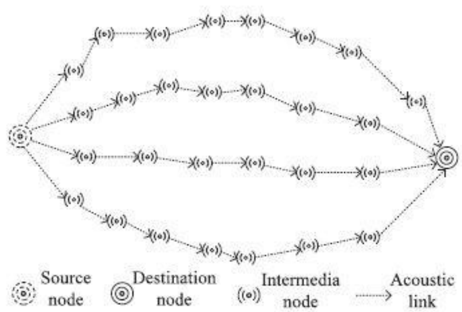

Figure.4. Network Architecture for Multi path Communication

The broadcast technology is handled in the origin node to deliver the same packets to the same target in multiple paths. Specifically, in the origin node, the data packet is encoded using Hamming Coding approach and is delivered using Multicast Ad hoc On- Demand Distance Vector (MAODV) protocol to establish multipath routing through the intermediate nodes. In each intermediate node, the data packet will be dropped without any further processing if any error occurs in its header. Otherwise, the used decoder of Hamming Coding will recover some corrupted segments into the original one if there are some errors in the corrupted packet, and then the packet will be transferred to the next intermediate nodes until it reaches the target. At the target, the decoder first corrects some errors encountered during transmission in the phonic channel for all received packets. Then, the received packets are classified according to the packet ID.

SEGMENT-BASED COMBINATION

The M-FEC scheme accesses all the segment sets $\{\hat{s}_k | 1 \leq k \leq v\}$, compares them in turn and chooses the segment that appears most frequently as the final data segment in its position. If two or more segment in the same position have identical count, the one appearing earlier is selected as the winner. Especially, if the domain "Flag" equals 1 after CRC checking in the packet header, all the segments in the packet are right and are regarded as the final ones. Thus, the kth final segment in the data packet is expressed as

$$\tilde{s}_k = \begin{cases} \hat{s}_{lk}, \text{"}Flag = 1\text{"} \ in \ lth \ received \ packet \\ \hat{s}_{ik}, \forall \ Count(\hat{s}_{ik}, \hat{s}_k) \geq Count(\hat{s}_{ak}, \hat{s}_k), \end{cases}$$

where $\hat{s}_{ak}$ is an arbitrary segment in $\hat{s}_{ik}$,

and $Count(\hat{s}_{ik}, \hat{s}_k)$ is the function of counting the number of $\hat{s}_{ik}$ in $\hat{s}_k$. All the final segments and the original header are combined and encapsulated into a new packet. Furthermore, this procedure applies to all the packet sets. The M-FEC program checks the final combined packets whether they are right or not using CRC data according to ID in the CRC packets. If all of them are right or the overall PER is even low, the target will send feedback to the origin to decrease the number of transmission paths. However, if the overall PER is high in an unacceptable range, the target will send feedback to the origin to increase the number of transmission paths. The procedure lasts until the overall PER is within a reasonable range. Thus, the number of paths can be maintained in a reasonable range. Additionally, the error packets will be requested to retransmit from the origin node by giving a repeat- request.

V. RESULTS AND DISCUSSION

A trajectory T in an anypath route R is a subgraph of R that connects the origin and the target. Note that a trajectory may simply be a walk (in graph language), but it can also contain branches, which could occur as a result of a duplicate transmission of a packet by more than one receiver. The cost of a trajectory is defined relative to the anypath route it traverses.

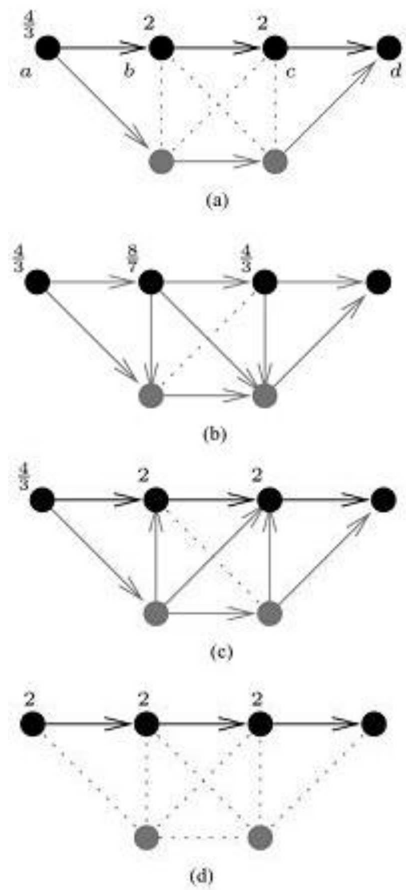

Figure .5. Cost Of A Trajectory In An Anypath Route.

Cost of the same trajectory T=(a,b,cd) traversing four different anypath routes. The cost d_{iJi}^{ETX} is annotated next to nodes a, b and c. (a) c(T|R) = 5.33. (b) c(T|R) = 3.81. (c) c(T|R) = 5.33. (d) c(T|R) = 6. In the form, four scenarios as in the above figure are shown along with their cost. Also, an option is provided to enter the number of candidate relays and enter delivery probability ratio. Above, the node „a" is having two candidate relays and so delivery probability ratio is 0.5. The cost of trajectory formula is applied and the cost will be displayed. In this form, the program listens in port number 10000 for data arrival. The same packet data arrived in varying times is displayed in list box controls. Then for each packet data, the total number of 1s in all packets in corresponding packet bit index is calculated and the bit 1 or 0 (occurring maximum number) is collected. Likewise all the bits are collected and 7 bits are added and displayed in text box control. Then for segment based approach, count of identical 7bit sequence is calculated and the bit sequence occurring maximum times are taken as final segment data. Suppose two 7bits sequences occurs equal times, then any one is selected as final segment data.

VI. CONCLUSION

In this thesis, it have proposed a novel FEC approach, namely M-FEC, designed with Hamming Coding for multiple- path transmissions in USNs. To the best of the knowledge, this is the first of its kind on segment-based packet combination and recovery technology for FEC with Hamming Coding which can improve both energy efficiency and reliability in USNs. The proposed M-FEC integrates multiple-path transmissions and Hamming Coding to Eliminate retransmission and enhance reliability. To reduce the consumed energy of transmission, the Markovian model is used to calculate the overall PER in order to make a decision for the number of multiple paths guaranteeing the desirable PER. The proposed approach can significantly outperform conventional multiple-path transm issions and single- path transmissions in terms of an energy efficiency and reliability. The new system is designed such {that those enhancements can be integrated with current modules easily with less integration work. The new system becomes useful if the above enhancements are made in future. The new system is designed such that those enhancements can be integrated with current modules easily with less integration work.

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