Frequency Synchronization Enhancement in Wireless Sensor Network using BAT Algorithm

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Abstract - Frequency synchronization is a cutting edge framework for any distributed systems. Wireless sensor networks have risen as an imperative and promising exploration territory in the current years. Frequency synchronization is an imperative for some, sensor organize applications that require extremely exact mapping of assembled sensor information with the frequency of the occasions happened. Biologically insprited, an innovative swarm intelligence algorithms are the most unique algorithms for enhancement. In this proposed work, new population based nature-impelled metaheuristic optimization algorithm, named Bat Algorithm (BA), is presented for upgrading the frequency synchronization in the distributed environment.

Keywords: Wireless Sensor Network, Frequency Synchronization, Metaheuristic Algorithm, Bat Algorithm.

I. INTRODUCTION

A wireless network is set up by utilizing the internet that comprises of different resources that can be accessed and associated from various geographic areas. The primary targets of the wireless network are to help the internet and versatility administrations while lessening the establishment cost. Remote Sensor System (RSS) is acquainted with additionally enhance the administration of the remote system regarding diminishing organization and support costs and in the meantime, attempting to build the system lifetime and security of the framework. The need to adjust in time and recurrence transmitters and collectors, i.e. to synchronize them, is a basic building hinder in correspondence frameworks. Synchronization is available in different structures on many levels of the correspondence chain.

For instance, recuperating the carrier frequency of the transmitter is important to rationally demodulate a received signal. Another type of synchronization requires hubs over the system to concur on a typical time reference. Synchronization wonders in nature are scientifically depicted by the hypothesis of pulse coupled oscillators (PCOs); every element normally sways and flickers intermittently, and coupling is performed through the discrete emanations of light. Every hub alters its inside reference while seeing flickers from its neighbors, and following basic standards, synchronization dependably develops after some time. The PCO synchronization rules are strikingly simple and robust, which makes their application to remote systems extremely engaging.

The rest of the contents is well-organized as follows. Section 2 describes the features of the various synchronizations. Section 3 presents the concept of Frequency Synchronization in remote sensor systems. Section 4 explained about the Bat Algorithm relates to frequency synchronization. Section 5 gives the experiment results. Section 6 conclusion and future enhancement.

II. VARIOUS SYNCHRONIZATIONS

The term synchronization is well-known to numerous digital communication engineers. For some, synchronization is confined to obtaining and following the transmitter's time at the receiver, so that synchronous demodulation can be performed. In any case, this is just a single type of synchronization, known as carrier or symbol synchronization. All the more by and large synchronization is critical in various ranges relying upon the level of reflection and the specific situation. This segment condenses the distinctive types of synchronization in tele communications, pointing out the objective of each.

Network Synchronization: Every single idea manage point-to-point synchronization, i.e. the receiver synchronizes to the timing of the transmitter. Network synchronization with respect to the operation of the network
would be benign for all nodes in the network to capitulate prevalent timing, aiming that all nodes can process synchronously with the others.

**Slot Synchronization:** It is derived from the hierarchy of network synchronization. For this specific type of synchronization, time is separated into interims, meant slots, and nodes over the network are required to concur on a typical reference moment that denotes a slot start. This type of synchronization is reminiscent of synchronization among fireflies: every node intermittently experiences a slot start or flashing moment, and synchronization is accomplished by adjusting these reference moments.

**Carrier Synchronization:** In remote communications systems, the baseband signal, which contains the tweaked symbols, should be up-changed over to a higher frequency before being physically transmitted. This higher frequency is named carrier frequency, and should be remade in phase and frequency at the receiver to perform lucid demodulation.

**Symbol Synchronization:** A digitally modulated symbols is regularly made out of sequence of pulses representing the transmitted symbols. Digital demodulation requires the beneficiary to perform symbol timing synchronization, with the goal that the received pulses are examined at the correct moment, and data is effectively separated. Consequently two parameters should be evaluated, specifically the symbol timing offset (STO) and the sampling clock frequency offset (SFO). This type of synchronization is in some cases alluded to as clock recuperation.

**Frame Synchronization:** After data has been extricated from the succession of pulses or from the subcarriers, frame synchronization is required to depict progressive data frames among the decoded bit stream. Synchronizing on the frame begin empowers to frame bytes and decide their part at various positions in the frames, e.g. decide client directs in Time Division Multiplexing (TDM) frameworks, or decide the doled out overhead capacities, for example, error check and control data.

**Bit Synchronization:** It is regularly utilized with two distinct implications. The initial one alludes to symbol synchronization in the extraordinary instance of binary bits. The second importance is more typical and indicates the synchronization of an asynchronous bit stream as indicated by the hardware local clock. This is expert by composing the asynchronous source into a support at their own arrival rate, and understanding them with the recurrence of the local clock.

**Data Synchronization:** At the client level, data file synchronization is extremely helpful while getting to also, changing information documents from various access points. A few illustrations incorporate keeping an email inbox up-to-date, and getting to the most recent rendition of a file. Commonly these information can be altered from various sources and additionally by various clients, and some procedure, named information synchronization, should be established with the goal that the most up-to-date form of the document is accessible to the client.

**Packet Synchronization:** In packet switched systems, the wellspring of data is part into packets that are transmitted or steered freely to their destination. For this situation, the receiver necessities to adjust the diverse deferrals of the received packets, so it can remake the original stream. It is accomplished by recovering authentic planning from the received packet arrangement through versatile methods.

**Multimedia Synchronization:** Multimedia alludes to the integration of heterogeneous components for example, pictures, text contents, audio and video in an assortment of application environments. These components can be acute time-needy, for example, audio and video in a film, can require time-requested introduction amid utilize. Multimedia synchronization manages the arrangement in time of these heterogeneous components, e.g. pictures, text, sound, video, in a Multimedia communications at various levels of combination.

### III. FREQUENCY SYNCHRONIZATION IN REMOTE SENSOR SYSTEMS

Network synchronization in telecommunications is characterized as disseminating or adjusting time and frequency over a network of clocks situated at various areas through the accessible communication implies. Synchronization is expected to conquer local clock errors and unavoidable transmission delays. [10]

Network synchronization brings various advantages that more often than not rely upon the application.
A few illustrations include:

1. Interferometry and facilitated multipoint-to-point transmission conspire, a relative time should be settled upon among transmitters with the goal that all transmit synchronously;
2. In cellular frameworks, every base station need to obey to a great degree exact frequency synchronization with the goal that they don’t transmit and meddle contiguous frequency bands.
3. Recording events in a medium transmission network, all nodes ought to concur on an universal time, for example, GMT;
4. Synchronization concerning the start and end of time slots, which is fundamental in media communications systems which require some type of TDMA conspire, for example, satellite systems, GSM versatile terminals, and so on.
5. Synchronization of clocks situated at various multiplexing and switching points in advanced broadcast communications systems.

These distinctive types of network synchronization are frequently arranged by their goal, i.e. concession to the frequency for arrange frequency synchronization, on a typical time for organize time synchronization, and on the slot start for network synchronization.

| Type                  | Terminology used             | Imperfection Addressed                     |
|-----------------------|------------------------------|---------------------------------------------|
| Frequency Synchronization | Rate Synchronization        | Targets at the agreement on the “tick” intervals between the clocks |
| Time Synchronization   | Offset Synchronization       | Targets at aligning the counter between the clocks |
| Slot Synchronization   | Phase synchronization        | Targets at making clocks tick concurrently |

Table III.I Network Synchronization Classification

Frequency synchronization in a network is characterized as the concession to the instantaneous frequency between neighboring nodes, i.e. \( \text{dF}\text{i}(t) = dt = \text{dF}\text{j}(t) = dt; \) \((i, j) \in E\) where \(E\) is the set of node pairs, however the initial total value \(F\text{i}(0)\) isn’t corrected. In other words, clock drift and phase noise in are revised to give a concurrence on a typical momentary frequency.

![Fig III.I Frequency Synchronization](image)

Note that frequency synchronization is misled with carrier synchronization. The two types of synchronization address the concession to a common frequency, yet they have particular objectives. Carrier synchronization aims point-to-point synchronization, the frequency and phase of the received signal is traced at the receiver, so the carrier frequency of the transmitter is accurately remade (see pic 3.1). Along these lines carrier synchronization infers that a masterslave approach is important. [16]

Frequency synchronization is more broad and includes synchronizing a network: the frequency of neighbourhood clocks are balanced, potentially in light of data from carrier synchronization, with the goal that remotely found clocks keep running at a similar frequency. A case of frequency synchronized clocks is appeared in Figure 3.1, where noise \(f(t)\) in the neighborhood oscillator is dismissed for effortlessness. From the meaning of frequency synchronized clocks given over, the time process \(t(t)\) of synchronized clocks have a similar slant, yet vary concerning their underlying initial offset \(t(0)\). Figure 3.1 further outlines the distinction amongst absolute
and relative frequency synchronization. The absolute frequency reference is appeared as the ideal clock \( t \), and relates to the meaning of the second given by the TAI. For absolute frequency synchronization, all nodes take after the total time \( t \) with the goal that \( dt = 1 \).

Frequency synchronization is an imperative errand required to work a telecommunication network. For instance, in mobile network systems, essentially the accuracy in the frequency of the radio signals to be transmitted.

IV. ECHOLOCATION OF MICROBATS WITH FREQUENCY SYNCHRONIZATION

Bats are fascinate creatures among the animal category. Bats are the only mammalians with pinions and they likewise have impelled ability of echolocation. Microbats size varies from the micro honey bee bat (1.4g to 2.1g) to the creature bats with wingspan more than 1.8m and weight up to 1.5kg. These microbats have lower arm length approximately 2cm to 10cm. Most bats uses echolocation to a particular degree; among each one of the creature classifications, microbats are an extraordinary case as microbats utilize echolocation comprehensively while largebats don't.

Most of microbats are apivorous. They use a kind of tracking system called as echolocation, to distinguish prey, avoid obstacles, and discover their roosting cleft oblivious. These bats transmit a noisy sound pulse and tune in for the reverberate that skips again from the surrounded objects. Their signal bandwidth differs relies upon the species, and frequently expanded by utilizing more harmonics.

While finding out for prey, the rate of pulse surge can be quickened to around 200 pulses for consistently when they fly near their prey. These short stable impacts derive the astounding limit of the signal processing energy of bats. Survey demonstrates the coordination time of the bat ear is typically around 301 \( \mu s \) to 400 \( \mu s \).

Generally the speed of sound in air is 340 m/s and wavelength \( \lambda \) of the supersonic sound overspill with a constant frequency \( f \) is given by \( \lambda = \frac{v}{f} \), which is in the range of 2.0 mm to 14.0 mm and frequency extend from 30 kHz to 160 kHz. Those wavelengths are in a ideal request of their prey sizes.

Especially, the imparted pulse would be as loud as 100 dB, and, fortunately, they are in the supersonic territory. The loudness differs from the greater end while searching down prey and to a lower base while homing towards the prey. Generally the scope of such short pulses travel couple of meters, unpredictable with the original frequencies. Microbats can findout the way to evade obstacles as small as thin human hairs.

Surveys expressed that microbats use the time delay from the exude and finding out the echo, the time deference between their two ears, and the loudness changes the echoes to produce three dimensional situation of the territory. They can discriminate the separation and intrusion of the objective, like prey, and speed movement of the prey, for example, little insects.

Clearly, a few bats have great visual perception, and most bats likewise have exceptionally delicate smell sense. As a general rule, they will utilize every one of the faculties as a mix to augment the effective searching of prey and fine route.

IV.I Bat Algorithm

We can make diverse bat-inspired algorithms by idealizing the echolocation of attributes of microbats [17,18]. Below are the simplified rules to utilize the algorithms...

**Rule 1:** The terminology “Echo-location” is used by the bats to calculate the distance. They have the capability of knowing the difference between feed and victim.

**Rule 2:** Bats are flying haphazardly with the speed / velocity \( v_i \) and position \( x_i \) and accordingly fine-tuning the emitted pulses and pulse rate emission \( r \in [0, 1] \) for the frequency of echolocation.

**Rule 3:** Bats loudness or din could change in many ways, the assumption made that the loudness differs from a larger positive value \( A_0 \) to lower value \( A_{\text{min}} \).
With the above rules are taken into account, the frequency \( f \) in a range \((f_{\text{min}} \text{ and } f_{\text{max}})\) identifies with the wavelengths \((\lambda_{\text{min}} \text{ and } \lambda_{\text{max}})\). Example, a frequency range of \((30 \text{ kHz and } 600 \text{ kHz})\) the scope of wavelengths \((0.9 \text{ mm to } 19 \text{ mm})\).

**Step 1:** Population initiation of \( n \) bats \( x_i \) \((i = 1, 2, ..., n) \) and \( v_i \)

**Step 2:** Frequency Initiation \( (f_i) \), Pulse Rate \( (r_i) \) also Loudness \( (A_i) \)

**Step 3:**

While \((t < \text{ maximum no. of iterations})\)

Produce new solutions by balancing frequency, and setting up velocities and locations or solutions

If \((\text{random} > r_i)\)

Determine the solution from the best solutions

Create a local solution nearing to the best solution selected

End if

Create a new solution by random flying

If \((\text{random} < A_i \& f(x_i) < f(x^*))\)

Agree with the new solutions

Increment \( r_i \) and decrement \( A_i \)

End if

Rate the bats and determine the current best \( x^* \)

End while

**Step 4:** Result Processing and Visualization.

**Pseudo code of the bat algorithm (BA).**

V. EXPERIMENT AND RESULT DISCUSSION

Synchronization error on multiple samples:

Fig V.I(a) Every point speaks to an example, that is a local time \( h_i \) of node \( N_i \) and an calculated local time \( h_j \) of node \( N_j \). Utilizing interjection procedures enhances the synchronization error. The strong line comes about because of a direct relapse on the samples, the dashed line is the consequence of a phase-locked loop (PLL).

Fig V.I(b) a similar thought can be utilized for lower (5) and upper (4) limits on the local time of \( N_j \). Additionally here, interjection can significantly enhance the synchronization error (i.e., on the vulnerability for this situation).

![Figure V.I Synchronization Error](image)

Execution assessment through recreation has the preferred standpoint that the subsequent accuracy or precision of all nodes does not need to be measured but rather is directly accessible. Hence, significantly larger systems can be assessed.
Frameworks and Topologies: Systems with 300 nodes are assessed, up to 600 hubs, randomly put in a square area. The transmission scope of the nodes is 20m in a square length of 90mts or 120mts. Distint transmission ranges from 0.4mts to 1mts are used as a part of a square of length 20m. The transmission run is fluctuated in the vicinity of 0.1 and 0.5 times the width of the square region, a chain of 5 nodes is reproduced.

Message Delays: For reproduction, various presumptions about the behaviour conduct of the framework must be made (e.g., about message delays). Measured defer follows from a 802.11 remote LAN are utilized, create postpone follows as indicated by an ordinary circulation. An additional offset is included which increments when the medium is saturated, that is when over 75% of the channel limit is utilized.

Check Drift: Each node is allocated an arbitrary however steady float rate between −100 ppm and +100 ppm. All nodes have a float rate of 50 ppm.

Results: The main concern is to analyze brought together and circulated forms of the LTS calculation as far as required messages and accomplished synchronization error. The average error is assessed as an element of the bounce separation to the master node. Assesses the synchronization error and the drift compensation error accomplished by the TS/MS calculations as a component of time. A hub one hop far from the master has an error of 1 ms following 83 minutes. A hub with five hops separate accomplishes 3 ms. The average synchronization error is assessed as a component of the quantity of messages traded between the nodes. The above said bat algorithm is better than other bio inspired algorithms as far as accuracy and efficiency [18]. On the off chance that we supplant the ranges of the frequency fi by random values and set values Ai = 0 and ri = 1, the bat algorithm turns into the standard particle swarm optimization (PSO).

VI. CONCLUSION

An alternative synchronization algorithm (Bat Algorithm) in view of the frequency synchronous character of bats was acquainted all together with build up a global frequency base that backings the execution of a frequency activated approach. This permits a collision free communication and a lessenings of energy utilization. The synchronization depends on a self-sorted out guideline with a simple calculations and provides adaptability and graceful degradation. This is helpful for the utilization in sensor networks. Besides, the extra rate calibration plot permits a more drawn out resynchronization interim and the utilization of shoddy oscillators with high float rates, which are normally highlighted in low cost hubs. The approach has been assessed by reproduction and an execution in a real testbed condition. A few analyses in light of an all-to-all topology have demonstrated that it is conceivable to accomplish a synchronization precision which is lower than 1 milliseconds.

REFERENCES

[1] Alazzawi, L. and A. Elkeeteb, 2008. Performance evaluation of the WSN routing protocols scalability. J. Comput. Syst. Netw. Commun., 2008: 481046-481054. DOI: 10.1155/2008/481046
[2] Almshreqi, A.M.S., B.M. Ali, M.F.A. Rasid, A. Ismail and P. Varahram, 2012. An improved routing mechanism using bio-inspired for energy balancing in wireless sensor networks. Proceedings of the International Conference on Information Networking, Feb. 1-3, IEEE Xplore Press, pp: 150-153. DOI: 10.1109/ICOIN.2012.6164367
[3] Altringham JD (1996) Bats: Biology and Behaviour, Oxford Univesity Press.
[4] Bains, V. and K. Sharma, 2012. Ant colony based routing in wireless sensor networks. Int. J. Electron. Comput. Sci. Eng., 1: 2516-2524.
[5] Dhurandher, S.K., S. Misra, M.S. Obaidat and N. Gupta, 2008. QDV: A quality-of-security-based distance vector routing protocol for wireless sensor networks using ant colony optimization. Proceedings of the IEEE International Conference on Wireless and Mobile Computing Networking and Communications, Oct. 12-14, IEEE Xplore Press, pp: 598-602. DOI: 10.1109/WiMob.2008.61
[6] Husna Jamal Abdul Nasir, Ku Ruhana Ku-Mahamad and Eiji Kamioka “Ant Colony Optimization Approaches in Wireless Sensor Networks: Performance Evaluation” Journal of Computer Science 2017, 13 (6): 153.164 DOI: 10.3844/jcssp.2017.153.164
[7] Jangra, A., A. Awasthi and V. Bhatta, 2013. A study on swarm artificial intelligence. Int. J. Adv. Res. Comput. Sci. Software Eng., 3: 259-263.
[8] Kaur, N. and S. Monga, 2014. Comparisons of wired and wireless networks: A review. Int. J. Adv. Eng. Technol., 5: 34-35.
[9] Maraiya, K., K. Kant and N. Gupta, 2011. Wireless sensor network: A review on data aggregation. Int. J. Scientific Eng. Res., 2: 1-6.
[10] Ranganathan, P. and K. Nygard, 2010. Time synchronization in wireless sensor networks: A survey. Int. J. Ubicomp, 1: 92-102. DOI: 10.5121/iju.2010.1206
[11] Richardson P (2008) Bats. Natural History Museum, London.
[12] Singh, A. and S. Behal, 2013. Ant colony optimization for improving network lifetime in wireless sensor networks. Int. J. Eng. Sci., 8: 1-12.
[13] Tyrrell, A and G. Auer. Imposing a reference timing on firefly synchronization in wireless networks. In Proceedings of the 65th IEEE Vehicular Technology Conference (VTC 2007-Spring), pages 222–226, Dublin, Ireland, April 2007.
[14] Tyrrell, A and G. Auer. Decentralized inter-base station synchronization inspired from nature. In Proceedings of the 68th IEEE Vehicular Technology Conference (VTC 2008- Fall), pages 1–5, Calgary, Canada, September 2008.
[15] Tyrrell. A and G. Auer. Decentralized slot synchronization for cellular mobile radio. DoCoMo Technical Journal, 10(1):60–67, June 2008.

[16] Tyrrell. A and G. Auer. Biologically inspired intercellular slot synchronization. EURASIP Journal on Wireless Communications and Networking, ID 854087:1–12, January 2009.

[17] Xin-She Yang and Amir H. Gandomi, Bat Algorithm: A Novel Approach for Global Engineering Optimization, Engineering Computations, Vol. 29, Issue 5, pp. 464–483 (2012).

[18] X.-S. Yang (Ed.): Bat Algorithm and Cuckoo Search: A Tutorial Artif. Intell., Evol. Comput. and Metaheuristics, SCI 427, pp. 421–434. springerlink.com _c Springer-Verlag Berlin Heidelberg 2013.

[19] Yang, X.S.: Nature-Inspired Metaheuristic Algorithms, 2nd edn. Luniver Press, UK (2010).

[20] Yang X-S (2010) A new metaheuristic bat-inspired algorithm, in: Nature Inspired Cooperative Strategies for Optimization (NICS0 2010) (Eds. Cruz C., Gonzalez J., Krasnogor N., and Terraza G.), Springer, SCI 284, pp 65-74.

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