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TO ACHIEVE ACCURACY FOR DATA DISSEMINATION IN DUTY-CYCLED WSNS

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Abstract* – Wireless sensors networks (WSNs) are decentralized systems where the sensors nodes are usually powered by batteries. The limited lifetime of sensors nodes imposes a severe constraints on the network performance and also on the energy conservation mechanisms in WSNs. Achieving these goals together is by no means trivial. One common approach to achieve energy efficiency and reliability in WSNs is Duty-Cycling. The Duty-Cycled nodes in WSNs switches between active and passive states and each node may determine its active/passive schedule independently .The main objective is to minimize the total transmission power for reliable data dissemination (Multicast/Broadcast) in DC-WSNs. Due to NP-Hardness problem, we design efficient algorithms with provable performance bounds. To facilitate our algorithm design we propose the concept of Time-Reliability power (TRP) space as a general data structure for designing data dissemination in WSNs, and provide guaranteed performance for both Broadcast and Multicast.

***Index Terms*- Energy efficient, reliability, routing scheduling wireless sensor networks.**

I. INTRODUCTION

WIRELESS sensor networks (WSNs) are decentralized system where nodes are usually powered by electric batteries. The limited battery lifetime have severe constraint on the network performance and energy conservation in WSNs. One common approach for achieving energy efficiency and network performance in WSNs is duty-cycling, where node switches between active and dormant states, and the active/sleeping schedule can vary independently from one node to another. As a result Duty-cycle in WSNs can easily implementable and is proved to energy efficient and reliable for data dissemination. The energy efficiency and reliability plays a very important requirement for data dissemination due to huge packet losses in the wireless communication system and also the limited power of the sensors nodes Achieving these two goals together is by no means trivial. On one hand, the Duty-Cycled nodes switches between active and sleeping states which has impact on the energy efficiency. And on the other hand nodes capacity to adjust the tx-power to different level brings out a trade off between energy efficiency and reliability as the nodes can increase its tx-power to improve link quality at the cost of high energy consumption. In this paper, the main objective is the main objective is to minimize the total tx-power for multicasting and broadcasting under guaranteed reliability and this algorithm is the first to holistically take into account the various aspects including Duty-Cycle, power adjustability and provide guaranteed performance bounds for energy efficient reliable data dissemination in DC-WSNs.

A. Background and Motivations

Always-Active Wireless Networks With Reliable Links

In the WSNs, multicasting is also one of the crucial components of wireless networking for the data dissemination. Therefore designing and energy efficient and reliable multicast protocol is also one of the paramount importance. In Always-active wireless ad hoc network the network topology is assumed to static and each forwarding node covers all of its neighbouring nodes in our transmission .And this problem was proved to be NP-hard, where its non-deterministic to prove which of the node is forwarding the data. Hence the work in propose an approximate and energy efficiency.

B. DC-WSNs With Reliable Links

In DC-WSNs with reliable links the wireless communication in assumed to be perfectly reliable and energy efficient where the number of destination node is small, where the nodes tx-power is assumed to be fixed and identical in min-energy multicast in DC-WSNs. However, the proposed work present a dynamic programming approach for the data dissemination under guaranteed performance

C. Always-Active Wireless Networks With Unreliable Links

The AAWNs, bares the similar objective as ours, i.e., the aim is to minimize the expected tx-power under guaranteed reliability. The fig 1 which did consider the multicast scenario, although a multicast tree was built, it works like a unicasting i.e., the nonleaf node in a multicasting tree transmit to its child node in a unicast way. Hence this algorithm is unreliable and has a negative impact on energy efficiency fig(b), where each of its nodes transmit the data to all of its nonleaf node in a multicasting fashion as shown in fig(c).

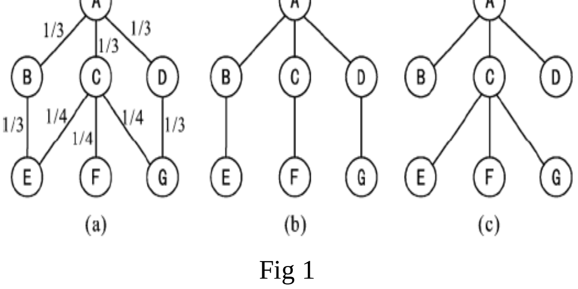


Fig 1

D. DC-WSNs With Unreliable Links

The DC-WSNs with unreliable links method has adopted an opportunistic flooding approach, where the BFs tree is exclusively constructed for broadcast. The opportunistic links outside the broadcast tree can be crippled under low duty-cycled. Hence this method might not be energy-efficiency and we also note that this method doesn't aim at guaranteed reliability and its is by means of no trivial for them to adopt to multicast case

II. *MODEL* & PROBLEM DEFINITION

The approximate algorithm designed to build a novel data structure called the Time-Reliability-Power (TRP) space, where data dimensions on time, reliability, and power levels .we believe TRP space algorithm can be used to optimize problem for data dissemination in WSNs and also which aims to minimize the total tx-power and energy efficiency for data dissemination.

Assume a set v of DC-WSN nodes where they switch between active/sleeping states based on time slots. The set of active time-slots in a working time of any node $U \in v$ which is denoted as $A(u) \subseteq I = \{1,2,3..I\}$ where I is the length of the working period. we assume that all nodes in v are time synchronized, and a node can wake up itself transmit data at any time-slot, but can only receive data when it is active.

In a data dissemination session in DC-WSNs, in order to avoid transmitting data to sleeping node, we provide the definition of Viable Data Dissemination Solution (VDS).

Definition 1 (VDS): Denote the set of nonleaf nodes in T by $\wedge(T)$ the child nodes of any node u in T by CT(u) and the set

$$\{v|v \in \mathcal{N}_u(l) \wedge t \in \mathcal{A}(v)\} \text{ by } \partial_t(u,l):$$

Assume T is a data dissemination tree with power assignment, and is a function that satisfies the following.

1) For any $t\epsilon I$ and any $u\epsilon \wedge(T)$ $S(u,t) \subseteq \delta t(u, L(u)) \cap Ct(u)$

2) For any $u\epsilon \wedge(T)$, $Ct(u) \subseteq S(u,t)$

Then S is denoted as viable transmission schedule for and <L,T,S> is denoted as viable data-dissemination solution (VDS). VDS requires a node $u\epsilon(T)$ for sending data to nodes in the set $S(u,t)$ at time-slot . Due to the link unreliability, we may have to retransmit several times for all the $S(u,t)$ to receive the data. To know how many retransmissions are needed for a forward node, we introduce Lemma 1.

Lemma 1: For any node $u\epsilon V$ any power level $l\epsilon L$ and any set $Q \subseteq Nu(L)$, let Xu(L,Q) be the random variable that denotes the number of transmissions required for all the nodes in to receive a data when tx-power is L. then we have

$$\mathbb{E}[\chi_u(l,\mathcal{Q})] = \sum_{i=0}^{\infty}\left[1 - \prod_{v\in\mathcal{Q}}(1-(1-p_{uv}(l))^i)\right].$$

Our objective is to find a VDS such that the expected total transmission energy of the forward nodes is minimized. We introduce the formal definition of this problem by Definitions 2.

Definition 2 (Energy-Consumption Function): The aim is to minimize the total transmission energy for the forwarding nodes. The energy consumption function of a VDS <L,T,S> is

$$\Psi(L,T,S) = \sum_{u\in\lambda(T)}\sum_{t\in\mathcal{I}} L(u)\cdot\chi_u(L(u), S(u,t)).$$

Definition 3 (ERDD Problem) : Given a set V of DC-WSN nodes, a source node $S\epsilon V$ and a set of receiver nodes the Energy-efficient Reliable Data Dissemination problem is to find a VDS <L,T,S> such that E{$\Psi(L*, T*. S*)$} is minimized As a special case of the problem, if all the network links are reliable and all nodes are active at all time-slots, then the problem degenerates to the min-energy broadcast/ multicast problem in traditional AAWNs with perfect links, which is known to be NP-hard.

TABLE I
FREQUENTLY USED NOTATIONS

$\mathcal{V}$	Set of duty-cycled sensor nodes
$\mathfrak{s}$	Source node for data dissemination
$\mathcal{R}$	Set of destination nodes for data dissemination
k	The cardinality of $\mathcal{R} \cup \{\mathfrak{s}\}$
$\mathcal{I}$	Set of all time slots in a working period
$\mathcal{A}(v)$	Set of v's active time slots in a working period
$\mathcal{L}$	Set of adjustable power levels of any node
$\mathcal{N}_v(l)$	Set of neighboring nodes of v when v's tx-power is adjusted to l
$\partial_t(v,l)$	Set of nodes in $\mathcal{N}_v(l)$ and active at time slot t
$\lambda(T)$	Set of non-leaf nodes in a rooted tree T
$\mathcal{C}_T(v)$	Set of the children nodes of v in rooted tree T
Δ	$\max\{\lvert\mathcal{N}_v(l)\rvert : v \in \mathcal{V}, l \in \mathcal{L}\}$
$p_{uv}(l)$	Quality of the link (u,v) when u's tx-power is l
$\gamma_{uv}(l)$	$1-1/\ln(1-p_{uv}(l))$ if $p_{uv}(l) < 1$, otherwise 1
γ^u_{max}	$\max\{\gamma_{uv}(l)\lvert l \in \mathcal{L} \wedge v \in \mathcal{N}_u(l)\}$
γ^u_{min}	$\min\{\gamma_{uv}(l)\lvert l \in \mathcal{L} \wedge v \in \mathcal{N}_u(l)\}$
$\chi_u(l,\mathcal{Q})$	Random variable denoting the number of transmissions by u for all the nodes in $\mathcal{Q} \subseteq \mathcal{N}_u(l)$ to receive a data packet when u's tx-power is l
$\Psi(L,T,S)$	Energy consumption function of the viable data-dissemination solution $\langle L,T,S\rangle$
$\phi(L,T,S)$	Function used to approximate $\mathbb{E}[\Psi(L,T,S)]$
λ	$\max\{\gamma^u_{max}/\gamma^u_{min}\lvert u \in \mathcal{V}\}$
$\vartheta(u)$	The Time-Reliability-Power (TRP) Set of u
$\mathfrak{F}$	Function used to map a TRP subspace to a graph whose nodes are all in $\mathcal{V}$
$\mathcal{U}$	Union of $\mathcal{V}$ and the TRP sets of the nodes in $\mathcal{V}$
ϖ	Weight function of any element or subset of $\mathcal{U}$
$\ell(h)$	Length of the TRP path h
$\langle\widehat{L}^*,\widehat{T}^*,\widehat{S}^*\rangle$	A VDS such that $\phi(\widehat{L}^*,\widehat{T}^*,\widehat{S}^*)$ is minimized
$\langle L^*,T^*,S^*\rangle$	A VDS such that $\mathbb{E}[\Psi(L^*,T^*,S^*)]$ is minimized
$\langle\mathcal{U},\mathcal{W}_M\rangle$	TRP space designed for the multicast case
$\langle\mathcal{U},\mathcal{W}_B\rangle$	TRP space designed for the broadcast case
$\langle L^b,T^b,S^b\rangle$	Approximate solution to the ERDD problem for the broadcast case
$\langle L^m,T^m,S^m\rangle$	Approximate solution to the ERDD problem for the multicast case
$\varrho_1(\mathcal{Y},\mathcal{W})$	Element closure of $\mathcal{Y}$ with respect to $\mathcal{W}$
$\varrho_2(\mathcal{Y},\mathcal{W})$	Relationship closure of $\mathcal{Y}$ with respect to $\mathcal{W}$
$in(x \rightsquigarrow y)$	Set of the elements in the shortest TRP path from x to y except y

III. APPROXIMATION ALGORITHMS

A. Solving ERDD for the Multicast Case

To design an approximation algorithm for multicast, we construct a TRP space with following rules.

M1) Two elements (u1,t1,r1,l1) and (u2,t2,r2,l2) in u\v are accessible to each other iff either u1=u2 or [u1 ∈ δt2 (u2, l2)] ∧ [u2 ∈ δt1(u1,l1) ∧ [r1≥ γu1u2(l1)] ∧ [r2≥ γu1u2(l2)] is true. M2) Two elements x=(u1,t1,r1,l1) ∈ u\v and u2 ∈ v are accessible to each other iff either u1=u2 or there exists y ∈ ϑ(u2)] such that (x,y) ∈ Wm.

Algorithm 1: MC-ERDD (v,s,R,I,U,Wm.L,A)

1 Use an approximate node weighted Steiner tree algorithm to find a Subspace (u',w') of (u,Wm) which contains R ∪ {s}. $\bar{U}$←U'
2 Let Tm be an arbitrary spanning tree of (U', W')
3 **foreach** $u \in \gamma$ (Tm) **do**
4 **foreach** $\vartheta \in$ CTm (u) **do**
5 **if** {(u',v) ∈ Wm | u' ∈ u' ∩ ϑ (u)} = ∅ **then**
6 Find (v,t,r,l) ∈ u'\\v such that $u \in \delta$t(v,l) and r≥ ζuv(l)
7 Select an arbitrary time slot t^ ∈ A(v) and add (u, t^, ζuv(l)
8 B ← CTm(u)
9 **foreach** t ∈ I **do**
10 $Sm(u, t)$ ← ∅
11 **foreach** $l \in \mathcal{L}$ **do**
12 r^ ← max{r'|(u, t, r', l) ∈ u|V V r' = 0}
13 Sm(u, t) ← Sm(u, t) ∪ {v' |$\gamma uv'$ (l) ≤ r^ ∧ v' ∈ B ∩ ∂t(u, l)}
14 B ← B − Sm(u, t)
15 **for each** node u in Tm **do**
16 J ← the set of u's neighboring nodes in Tm

B. Solving ERDD for the Broadcast Case

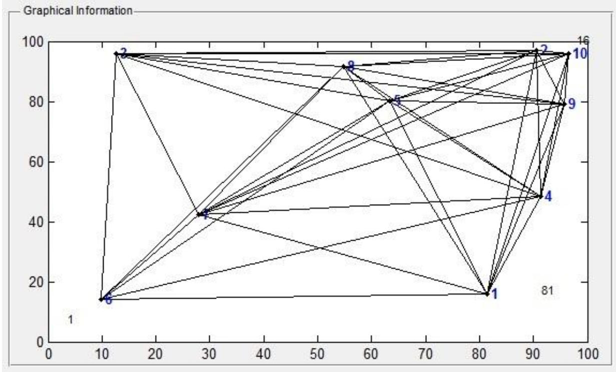
Multicast algorithm can also be used for broadcast, we represent another algorithm for the broadcast case which has a better approximation ratio. Again, the first we create a TRP space but the access-relationship is defined differently from according to the following rules.

Algorithm 2: BC-ERDD (v,s,I,uWB,L,A)

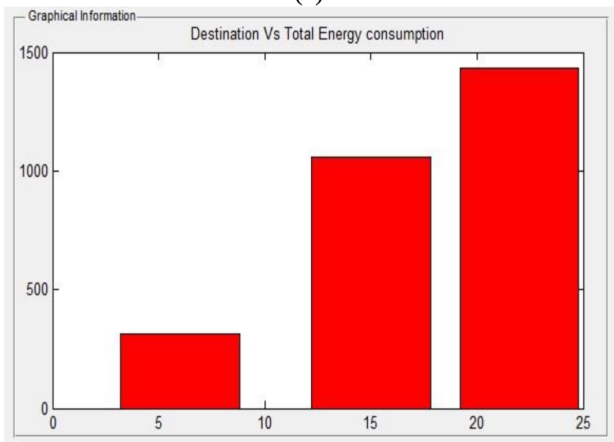
1 X ← ∅, Z ← V − {s}
2 **while** |Z| > 0 **do**
3 Find a ∈ U and a non-empty set D ⊆ Z such that (|D| ≥ 2 ∨ a = s) = true and $avl(a, D)$ is minimized. Let b be the node-image of a
4 A ←∪y∈D in(a →y)
5 X ← A ∪ X
6 Z ← Z − %1(A, WB)
7 **if** b 6≠ s **then** Z ← Z ∪ {b}
8 Let Tb be an arbitrary directed spanning tree of ℑ (ϱ1(X, WB), ϱ2(X, WB)) rooted at s
9 Set Lb, Sb for the nodes in Tb using the same method as lines 8-18 of Algorithm 1
10 **return** (Lb, Tb, Sb)

IV. PERFORMANCE EVALUATION

The evaluation of extensive simulations for the performance of our algorithms. In the simulations, the random deploy V nodes in a square of 10V and set the maximum tx-power is set to 15.0 dBm. The source/destination nodes are selected randomly and the link qualities are set by considering the path-loss channels. The reported data in our figures are the average of 50 simulation results.



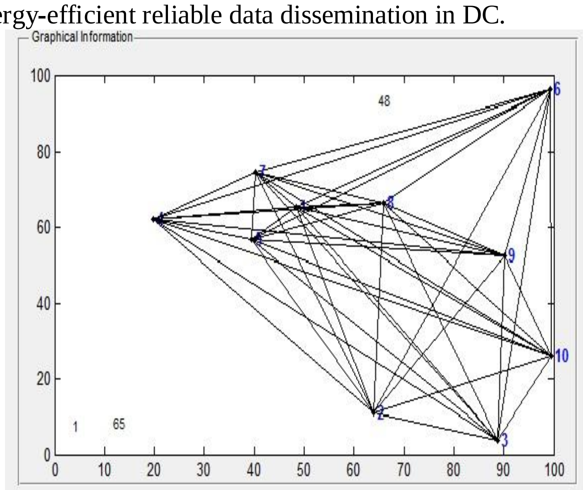
(a)



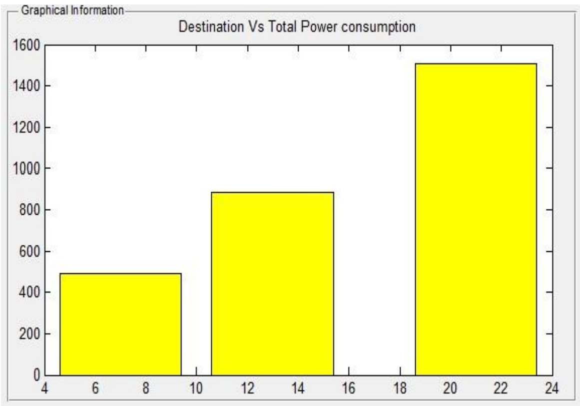
(b)

Fig1: (a) Deployment of nodes and link connectivity between nodes in MC_ERDD (b) Studying the impact of power adjustability in MC_ERDD

Finally, we study the impact of power adjustability on energy consumption. Here we plot a graph for different iterations for different number of nodes and for different transmission power. In the fig1 & fig 2 we can observe the different network topology graph and its simulation results for different iterations under guaranteed performance bounds for energy-efficient reliable data dissemination in DC.



(a)



(b)

Fig2: (a)Deployment of nodes and link connectivity between nodes in BC_ERDD (b) Studying the impact of power adjustability in BC_ERDD

V. CONCLUSION

The data dissemination in Duty-Cycled WSNs, where we seek to minimize the total TX-Power and energy for the reliable data dissemination for both Multicasting and Broadcasting. Due to NP-hard problem in the existing system, we proposed approximate algorithm Time Reliability Power (TRP) space with provable performance ratios. Additionally we also calculate the TX-Power and energy for different iterations for different number of nodes which helps to analysis the TX-Power and energy for data dissemination. Also to best of our knowledge, this algorithm is the first to holistically take into account the various aspect including duty-cycled, power adjustability and to provide guaranteed performance bounds for energy-efficient reliable data dissemination in DC-WSNs.

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