On the Relevance of Using Interference and Service Differentiation Routing in the Internet-of-Things

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2 Proposed Solution
3 Simulation and Performance Evaluation
4 Conclusion & Perspectives

1 Motivation and Background

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Motivation

- Ubiquitous Sensor Networks (USNs) are built upon the integration/networking of RFID, WSN and mobile devices to enable a common communication platform capable of identifying the objects, sensing what is happening in the environment, pervasive access to a variety of information.

-When endowed with an IP (or global) @, objects and things are transformed into *"smart objects"* capable of using the Internet to communicate among themselves (*m2m*), and with humans in the *"Internet-of-the-Things (IoT)".*

-This will provide access to the information *anytime, anywhere*, to *anyone,* about *anything.*

Motivation

- RFID and WSN are central components of the future IoT applications.

- RFID systems are used in such environments to accurately identify objects, while WSN are used for monitoring the surrounding environment, & localization.

- The integration of RFID/WSN technologies: Hardwar, system level.

- Both yield a *hybrid System*, offering different services, and with different capabilities and energy resources.

Motivation

-Traditional WSN routing (data collection) protocols have been relying on homogeneity and designed on a routing model that route sensor readings from nodes to a gateway, by assuming the sensor nodes are of the same fabric and expected to deliver the same services.

- The application of these routing protocols in the heterogeneous IoT settings may lead to performance degradation as different nodes might exhibit different services.

Background

Load balancing solutions:

-Node deployment solutions: increase the number of nodes near the base station to prevent holes that may be caused by battery depletion of dominating nodes.

- Multi-path traffic balancing routing: but equally among all nodes (homogenous environment assumption).

Service differentiation in WSN:

with respect to the traffic classes and requirements, still in homogeneous environment. This differs from the solution proposed herein where service differentiation is related to the delivered services of the sensor nodes in a heterogeneous environment.

Background

- Data collection protocols e.g. collection tree protocol (CTP), TinyOS beaconing (TOB) and RPL are closely related to the routing protocol proposed in this work.
- Designed around a collection tree structure
- All assuming a homogeneous environment.
- TOB: Simplicity, but: i) uneven power consumption, ii) lacks of resilience against node failure & interference

Aim: Extend TOB to heterogonous environment while tackling its shortcomings.

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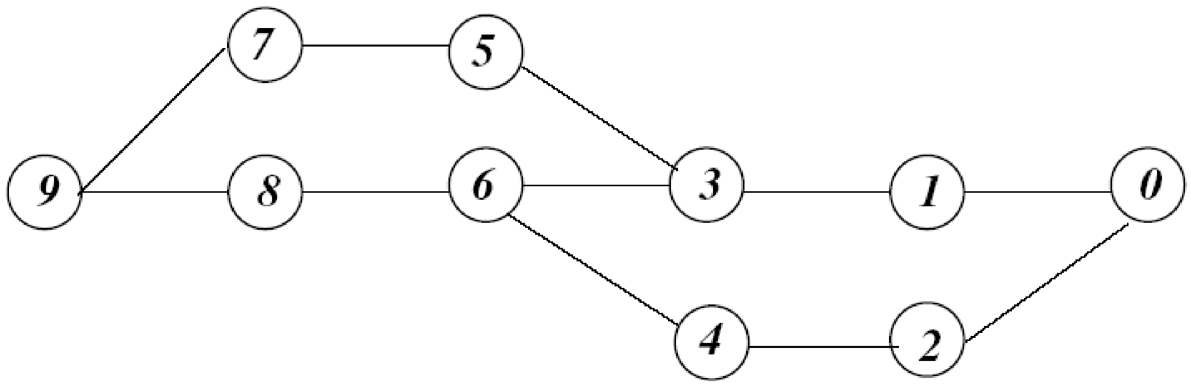
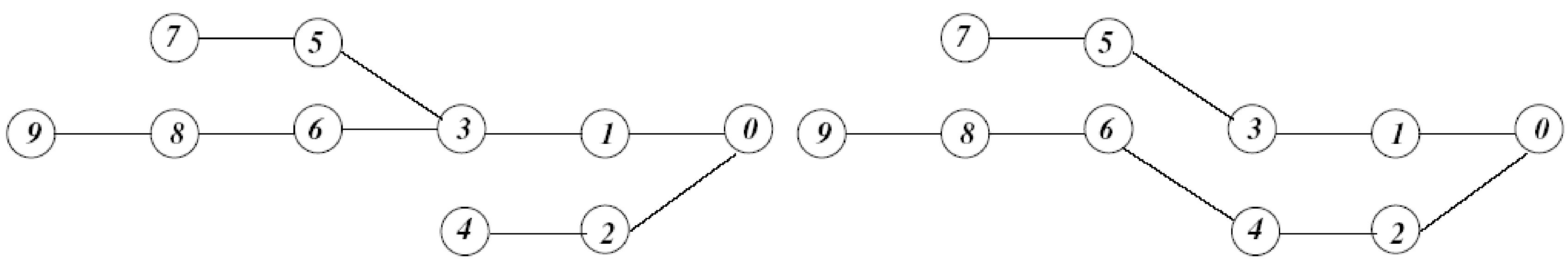
Proposed Solution



Network Topology Connectivity



(a) Path Multiplexing Configuration (b) Path Separated Configuration

Path Discovery

Proposed Solution

The proposed solution (LIBA) balances between:

- Interference-aware routing: to minimize traffic flows interference on nodes → balancing energy usage. It also reduces the impact of node failures by having less branches cut from the network upon failure.
- Service-aware routing: to protect critical nodes (that provide more services or having less power) from being overused.

Proposed Solution

$$\begin{array}{ll} \min & \sum_{\jmath \in \mathbf{N}[n]} x_\jmath \\ \textit{subject to} & \end{array} \qquad (1)$$

$$\begin{cases} w(n) & = \alpha w_i(n) + \beta w_s(n) \quad (2) \\ parent(\jmath) & = n \mid w(n) = \min_{x \in \mathcal{N}(\jmath)} \{w(x)\} \quad (3) \\ x_\jmath & = 0 \text{ or } 1 \text{ , } \forall \jmath \in \mathbf{N}[n] \quad (4) \end{cases}$$

$$x_\jmath = \begin{cases} 1 & \text{parent}(\jmath) = \text{n} \\ 0 & \text{otherwise.} \end{cases}$$

$$\beta = \begin{cases} 0 & \text{Interference-aware routing} \\ 1 & \text{Service-aware routing} \\ x \in]0 \ldots 1[& \text{Hybrid routing.} \end{cases}$$

Minimizing the number of children (1), where parents are selected by minimizing the node weight (3), defined by combining interference weight & service weight (2).

Proposed Solution

- LIBA is a heuristic for the previous zero-one linear model, and LIBP represents its implementation (protocol).
- It uses a scheme similar to TOB for the creation of a breadth-first spanning tree rooted at the sink,
- through recursive broadcasting/recording of routing update beacon messages and selection of parents, periodically in every ***epoch***, but with
- a slight modification to the beaconing process in order to meet the proposed routing constraints:

Proposed Solution

- To implement the proposed parent selection model, the sensor nodes wait to hear from a set of neighbors before selection, instead of immediately selecting the first parent node they heard from.

- Upon reception of the beacons from potential parents, the children nodes select their least weighted parent and update their forwarding tables (Eq. 3).

Proposed Solution

- When broadcasting the beacon after the initial step, the parent computes its weight (Eq. 2). It then includes the calculated weight in the beacon that is being broadcasted.

- By piggy-backing the parent's weight into the beacon broadcasting Process, signaling overheads related to the addition of an acknowledgement into the routing process is avoided (contrary to CTP).

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Simulation Parameters

Simulation Setup

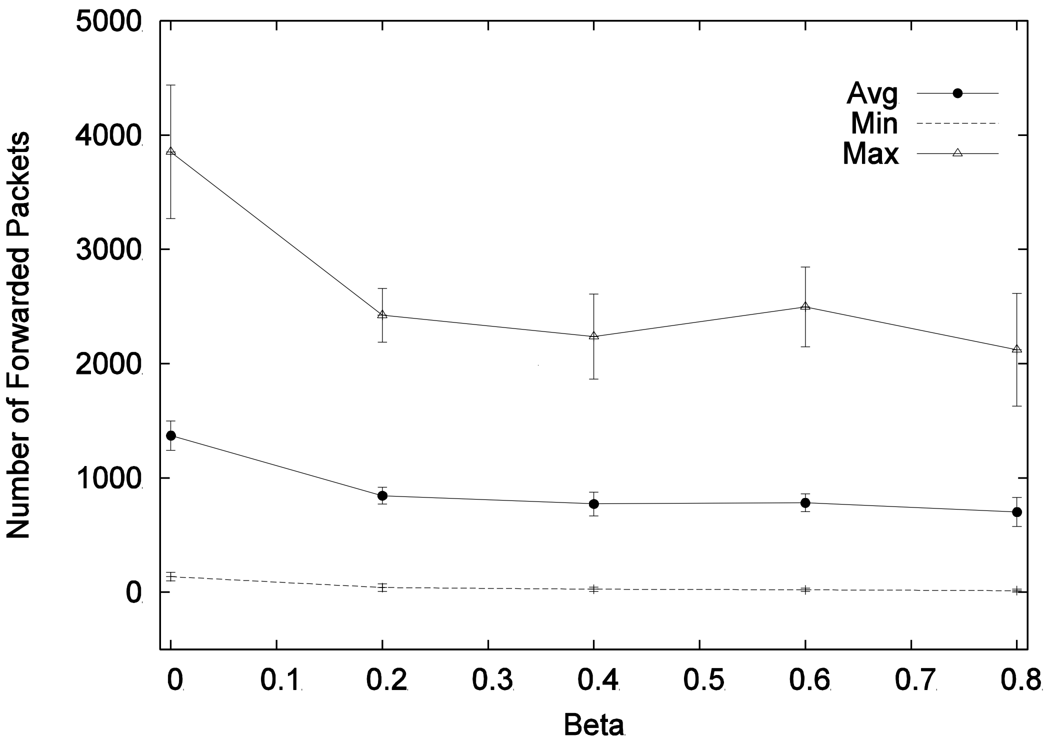
Traffic	every node sends a 28-byte packet every 5 sec
Number of nodes	20: 200
Topology	random
Simulation duration	900 sec
beacon interval	20 s

Simulation Metrics

- Load balancing and critical nodes consideration: The number of packets forwarded by critical nodes (CN) and its dispersal.
- Number of packets received by the sink/sent by nodes vs. time: data collection latency, traffic dispersal over time.
- Overall energy consumption.

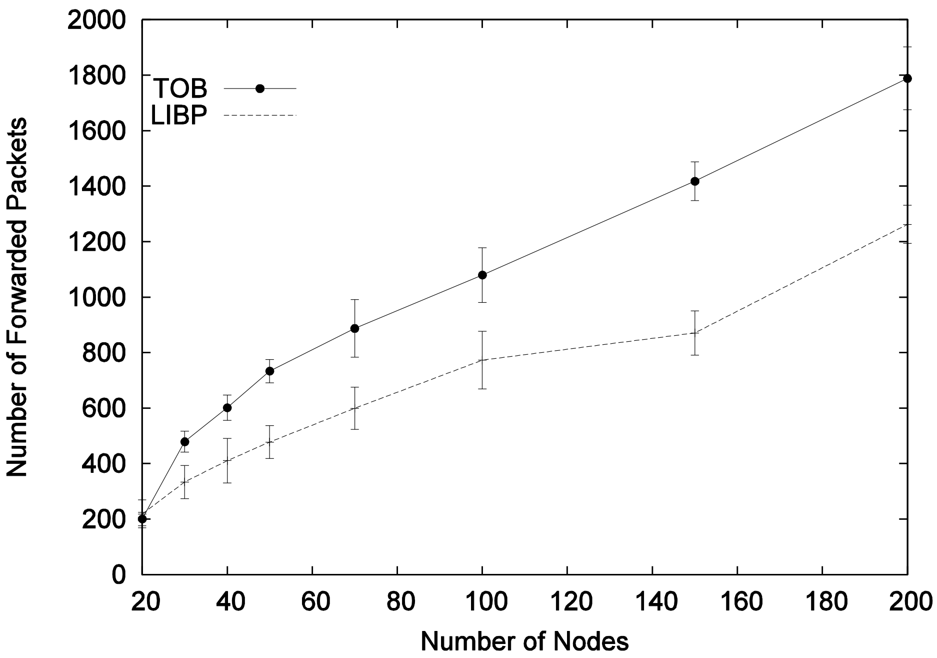
Simulation Results
(Forwarding of CN)

- 100 nodes, 10% CN.
- Min/Max/AVG # packets forwarded by CN vs. β (amongst 18000 generated packets)
- β =0.4 has been sufficient enough to enable relaxing routing load at critical nodes



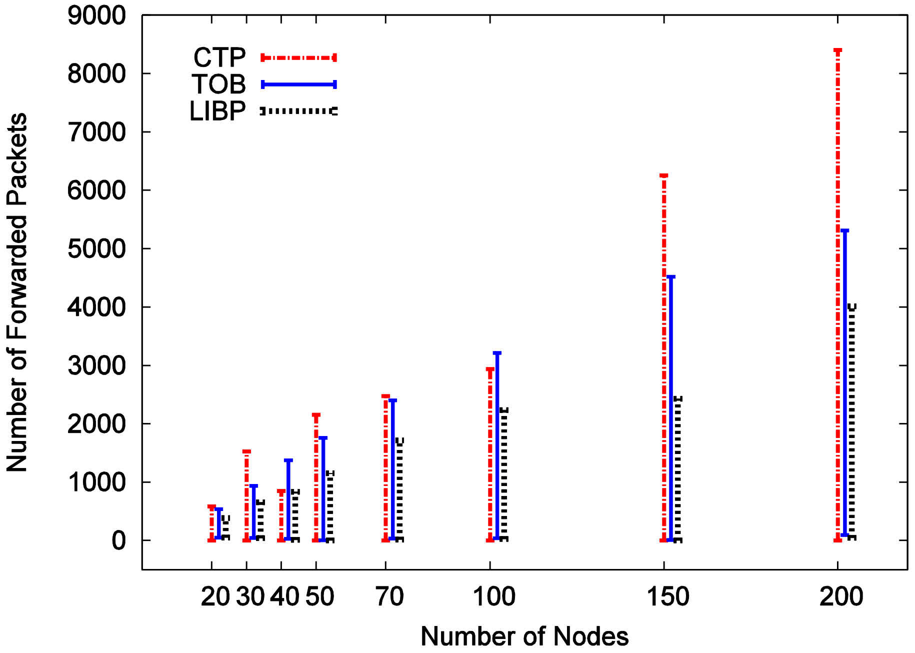
Simulation Results
(Forwarding of CN)

- Average # of packets forwarded by CN.
- CTP: very high and fluctuating results with a high error bars (interfering with TOB).
- LIBP: smooth increase, the difference vs. TOB becomes more important as the # of nodes rises, which gives more choices & enables routing around CN.

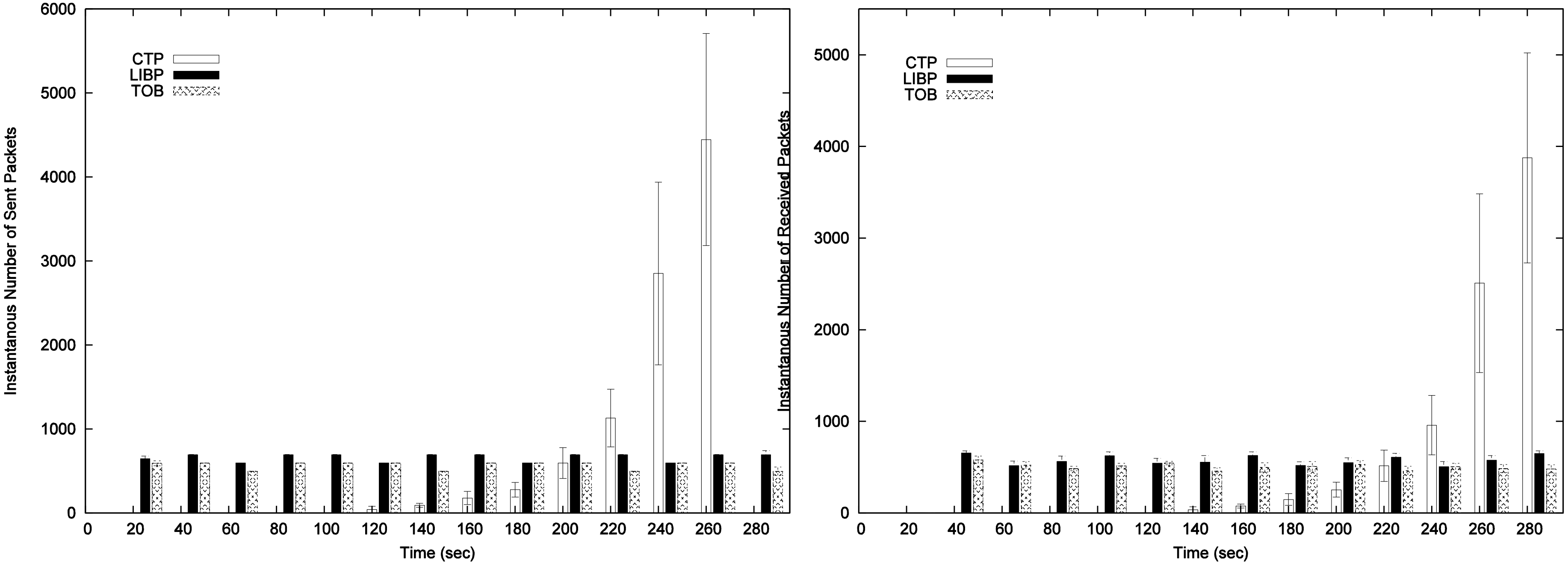


Simulation Results
(Forwarding of CN)

- Interval of the number of forwarded packets by critical nodes (the minimum/maximum dispersal).
- CTP creates the most bottlenecks, LIBP the best load balancing.

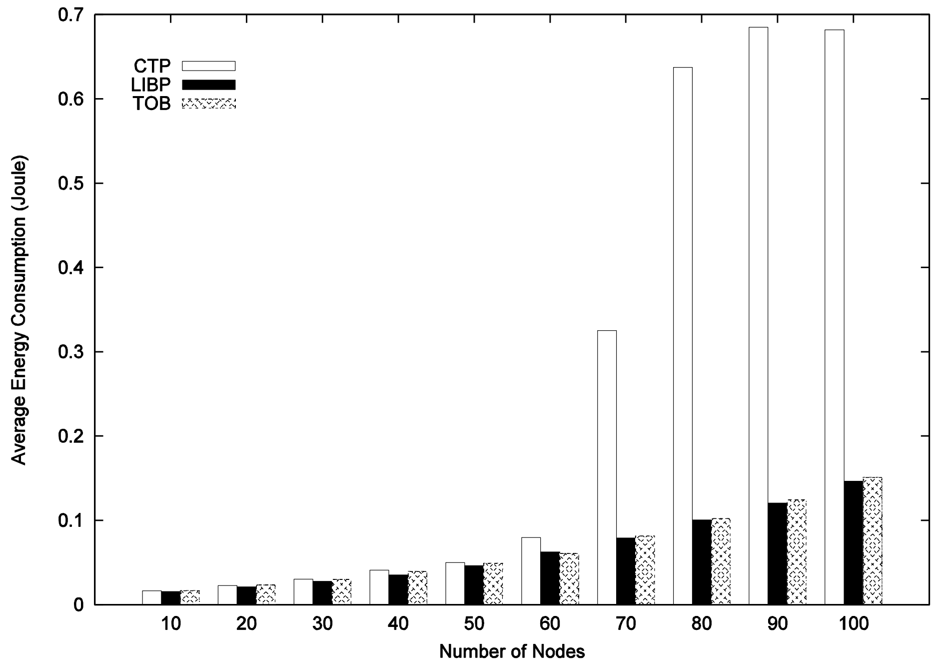


Simulation Results
(sent/received packets vs. time)



- CTP takes a very long time for spanning tree construction, delay packet delivery and concentrates it in few epochs→ Increased latency and interferences.

Simulation Results
(Energy Consumption using Avrora)



- CTP energy consumption dramatically increases from 70 nodes.
- LIBP: the lowest values.

Conclusion

- The Future IoT is expected to be featured with a high degree of node heterogeneity in terms of capacity and services.
- LIBP is proposed; a new routing protocol built upon routing simplicity, minimization of the interference and service differentiation among heterogeneous nodes to achieve load balancing, efficient traffic engineering for USNs that will form the future IoT.
- Preliminary experimental results with TOSSIM/AVRORA reveal superiority of LIBP compared to CTP and TOB protocols, in terms of load balancing the traffic and routing around critical nodes, fast tree construction/data collection, reducing the overall energy consumption.

Perspectives

- There is room for further investigation of LIBP in terms of its fault tolerance capabilities upon failure, its dependability in terms of protection against jamming attacks,
- its relative performance compared to recent protocols such as RPL.
- Real implementation on a tested, notably with RFID and hybrid nodes, instead of just sensor motes.