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femto-st SCIENCES & TECHNOLOGIES

Vue d'ensemble sur mes travaux de recherche (5 dernières années)

Réseaux de capteurs scalaires

- **Routage localisé** : la décision du routage est prise localement en utilisant uniquement l'information 1-hop.
  - Ahmed Mostefaoui, Mahmoud Melkemi, Azzedine Boukerche: "Localized Routing Approach to Bypass Holes in Wireless Sensor Networks." IEEE Trans. Computers 63(12): 3053-3065 (2014)
  - Ahmed Mostefaoui, Mahmoud Melkemi, Azzedine Boukerche: "Routing through holes in wireless sensor networks." MSWiM 2012: 395-402

- **Fusion de données** : approches sérialisées plus efficaces mais plus complexes à développer.
  - Mohammed Amine Merzoug, Azzedine Boukerche, Ahmed Mostefaoui, Samir Chouali: "Spreading Aggregation: A distributed collision-free approach for data aggregation in large-scale wireless sensor networks." J. Parallel Distrib. Comput. 125: 121-134 (2019)
  - Mohammed Amine Merzoug, Azzedine Boukerche, Ahmed Mostefaoui: "Efficient information gathering from large wireless sensor networks." Computer Communications 132: 84-95 (2018)
  - Azzedine Boukerche, Ahmed Mostefaoui, Mahmoud Melkemi: "Efficient and robust serial query processing approach for large-scale wireless sensor networks." Ad Hoc Networks 47: 82-98 (2016)
  - Ahmed Mostefaoui, Azzedine Boukerche, Mohammed Amine Merzoug, Mahmoud Melkemi: "A scalable approach for serial data fusion in Wireless Sensor Networks." Computer Networks 79: 103-119 (2015)

Vue d'ensemble sur mes travaux de recherche (suite…)

Réseaux de capteurs multimédias

- **Contrôle distribué** : contrôler, de manière distribuée, le débit des données vidéo tout en tenant compte des contraintes du réseaux (consommation énergétique, qualité des liens, etc.).
  - Nesrine Khernane, Jean-François Couchot, Ahmed Mostefaoui: "Optimal power/rate trade-off for internet of multimedia things lifetime maximization under dynamic links capacity." Future Generation Comp. Syst. 93: 737-750 (2019)
  - Nesrine Khernane, Jean-François Couchot, Ahmed Mostefaoui: "Maximum network lifetime with optimal power/rate and routing trade-off for Wireless Multimedia Sensor Networks." Computer Communications 124: 1-16 (2018)

- **Sécurisation :** sécuriser les images transmises en préservant les ressources du réseau
  - Ahmed Mostefaoui, Zeinab Fawaz, Hassan N. Noura: "A robust image-encryption approach against transmission errors in Communicating Things Networks." Ad Hoc Networks 94 (2019)
  - Ahmed Mostefaoui, Hassan N. Noura, Zeinab Fawaz: "An integrated multimedia data reduction and content confidentiality approach for limited networked devices." Ad Hoc Networks 32: 81-97 (2015)

- **Couverture périphérique** : ordonnancer l'activité des nœuds de telle sorte à assurer une couverture périphérique.
  - Amor Lalama, Nesrine Khernane, Ahmed Mostefaoui: "Closed Peripheral Coverage in Wireless Multimedia Sensor Networks." MobiWac 2017: 121-128

Vue d'ensemble sur mes travaux de recherche (suite…)

Réseaux de véhicules connectés et mobilités (en collaboration avec PSA Peugeot Citröen)

- **Big data** : accélération et passage à l'échelle des applications V2I.
    - Amir Haroun, Ahmed Mostefaoui, François Dessables: "Data fusion in automotive applications." Personal and Ubiquitous Computing 21(3): 443-455 (2017)
    - Amir Haroun, Ahmed Mostefaoui, François Dessables: "A Big Data Architecture for Automotive Applications: PSA Group Deployment Experience." CCGrid 2017: 921-928
    - Anthony Nassar, Ahmed Mostefaoui and François Dessables: "Improving bid-data automotive applications performance through adaptive resource allocation". IEEE Symposium on Computers and Communications 2019: 49-55 Barcelona

- **Protocole de communication** : développement et vérification de protocoles spécifiques (MQTT-CV).
    - Samir Chouali, Azzedine Boukerche, Ahmed Mostefaoui: "Towards a Formal Analysis of MQtt Protocol in the Context of Communicating Vehicles." In the 15th ACM MOBIWAC 2017, Miami, FL, USA, November 21 - 25, 2017. ACM 2017, pages: 129-136
    - Samir Chouali, Azzedine Boukerche, Ahmed Mostefaoui: "Ensuring the Reliability of an Autonomous Vehicle: A Formal Approach based on Component Interaction Protocols." In the 20th ACM IMSWiM 2017, Miami, FL, USA, November 21 - 25, 2017, pages: 317-321, Best Short Paper Award.

- **Ville connectée et mobilité :** cartographie temps réel des places de stationnement disponibles au niveau d'une ville.
    - Mohammed Amine Merzoug, Ahmed Mostefaoui, Abderrezak Benyahia: "Smart IoT Notification System for Efficient In-City Parking." ACM Q2SWinet 2019: 37-42

Vue d'ensemble sur mes travaux de recherche (suite…)

Réseaux WBAN

- **Maintien des personnes âgées à domicile** : système intégré d'aide et d'alerte en cas de malaise.
  - Moustafa Fayad, Ahmed Mostefaoui, Samir Chouali, Salima Benbernou "Fall Detection Application for the Elderly in the Family Heroes System." ACM MobiWac 2019: 17-23

Scalable Approaches for Serial Data Fusion in Wireless Sensor Networks

A. Mostefaoui[1], A. Boukerche[2], M. A. Merzoug[1] and M. Melkemi[2]

[1]University of Franche-Comté, France

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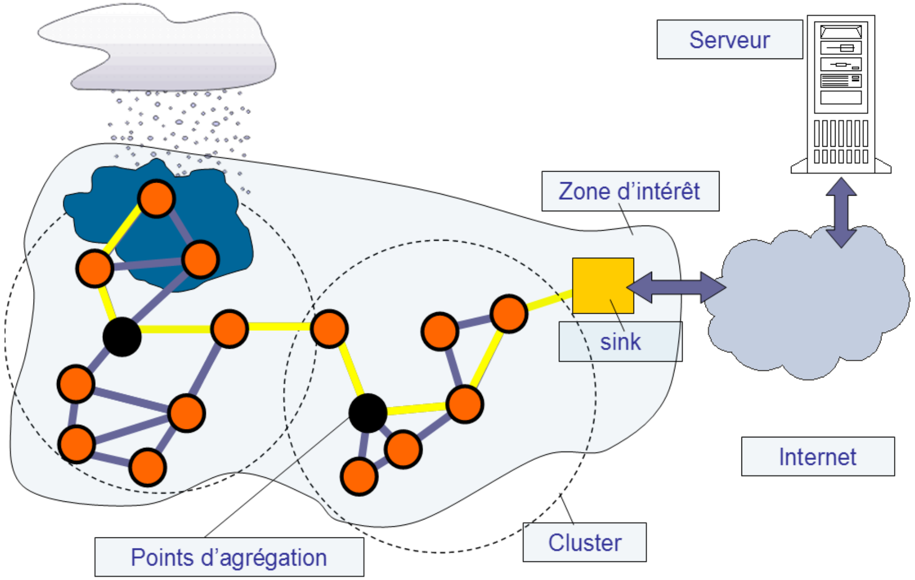
[3]University of haute Alsace, France

Query Processing in WSNs

Wireless sensor networks



Objective : answer queries like:

```
SELECT AVR (temp), MAX (hum), MIN (light), COUNT()
FROM sensors
```

Query Processing in WSNs

- Warehouse approaches: raw data is first sent to the sink before query processing; i.e., two independent processes.
  - Query precision.
  - Overutilization of the network resources and poor scalability.

- In-network centralized approaches: a tree rooted at the sink is constructed and data is aggregated in intermediate nodes.
  - Reduced utilization of network resources in comparison to warehouse approach,
  - Vulnerability and poor scalability.

Query Processing in WSNs

- Distributed approaches: derive an estimate of a parameter or function of interest from raw (sensed) data. The estimate is successively (i.e., iteratively) carried out through local computations from the exchanged data between immediate neighbors.
  - No central base station is required,
  - Multi-hop communications are avoided (no need to maintain rooting data),
  - Robustness and good scalability.

  - Important communications consumption to reach the convergence,
  - Query response time particularly high due to their iterative nature on one hand and to the number of packet collision they generate on the other hand.

Query Processing in WSNs

- Serial approaches: the estimate is successively (i.e., serially) updated from node to node until all nodes in the network are visited. The last node holds the right estimate.

  – Very efficient in terms of reducing communications compared to centralized and distributed approaches.

  – Require the construction of an Hamiltonian path through the network (Known to be NP-Complete problem),
  – The cost of finding such a path, in a "decentralized" manner to ensure scalability, is very high,
  – High vulnerability

M. Rabbat and R. Nowak. "Quantized incremental algorithms for distributed optimization". IEEE Journal on Selected Areas in Communications, 23(4):798-808, 2005.

Query Processing in WSNs

Question: how could serial approaches meet WSNs requirements (i.e., completeness, scalability and robustness) whilst maintaining their performances?

Outline

- Our approach: Peeling Algorithm (PA)
  - Boundary Traversal Algorithm
  - PA Overview
  - Starting Node Detection
- Proof of Correctness
- Enhanced PA
- Performance Evaluation
- Conclusion and Future Works

Peeling Algorithme

- Requirements:
  - Serial nature,
  - Decentralized and Localized: no extra-knowledge than what is already available (i.e., information about immediate neighbors and their locations) is used in order to meet scalability requirement,
  - Query Completeness: all nodes contribute in the query; i.e., it should visit all nodes in the network,
  - Random topology: could handle all network topologies.

- Assumptions:
  - Nodes know their geographical locations and those of their immediate neighbors,
  - All nodes are connected (network connectivity),
  - The Query Initiator Node (QIN) could be any node in the network (often the sink),
  - UDG Model

Peeling Algorithme

Definitions:

Definition 1 (*Hole*). A hole is a closed region that is free of nodes and bounded by the polygon formed from the set of non-intersecting links, modeled as line segments, of at least four nodes. This set of nodes is called the boundary of the hole.

Definition 2 (*Boundary node*). A node N is said to be a boundary node (BN) in the direction $\angle N_iNN_j$, iff it has at least two angularly adjacent neighbors N_i, N_j so that N_i cannot communicate with N_j or the angle $\angle N_iNN_j \geqslant \pi$.

Definition 3 (*Network boundary nodes*). Network Boundary Nodes (NBN) s are defined as the set of BNs such that the polygon formed from the corresponding set of links, considered as straight non-intersecting line segments, contains all nodes of the network.

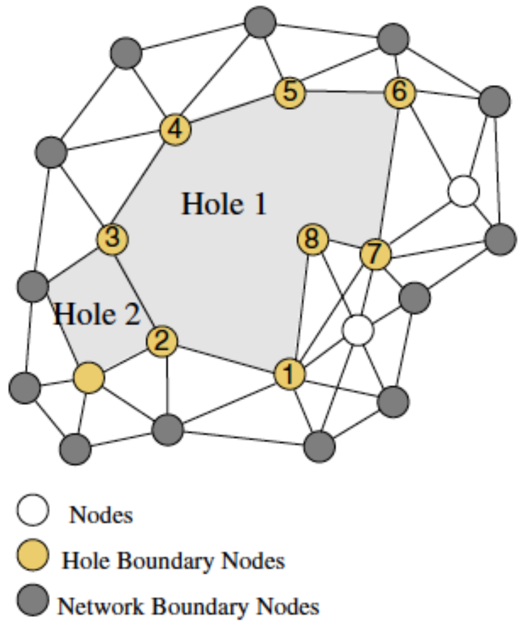
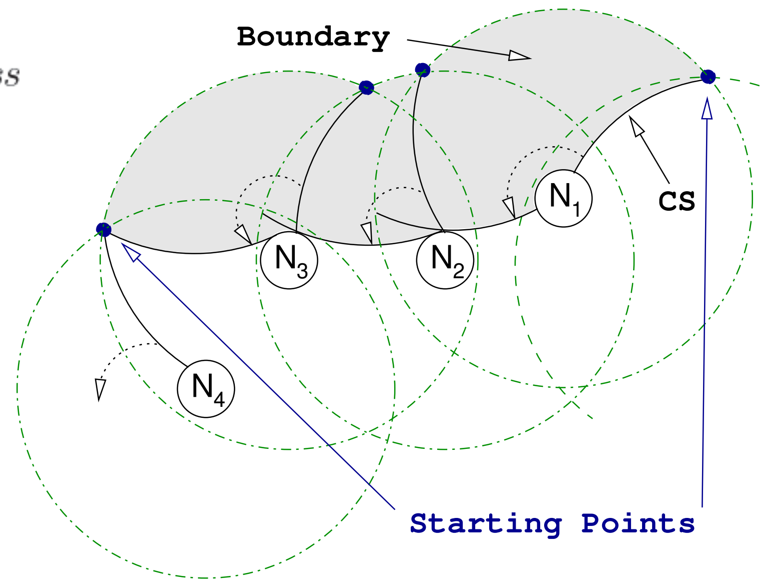


Fig. 1. Boundary nodes.

Peeling Algorithme

Boundary Traversal Algorithm: whenever started from a boundary node, all visited nodes belong to the same boundary.

Theorem 1.
Whenever started from a boundary node, curved stick process ensures boundary traversal.



A. Mostefaoui, M. Melkemi and A. Boukerche *"Localized Routing Approach to Bypass Holes in Wireless Sensor Networks"* IEEE Transactions on Computers, 63(12):3053—3065, Sep. 2014

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Peeling Algorithme

Overview:

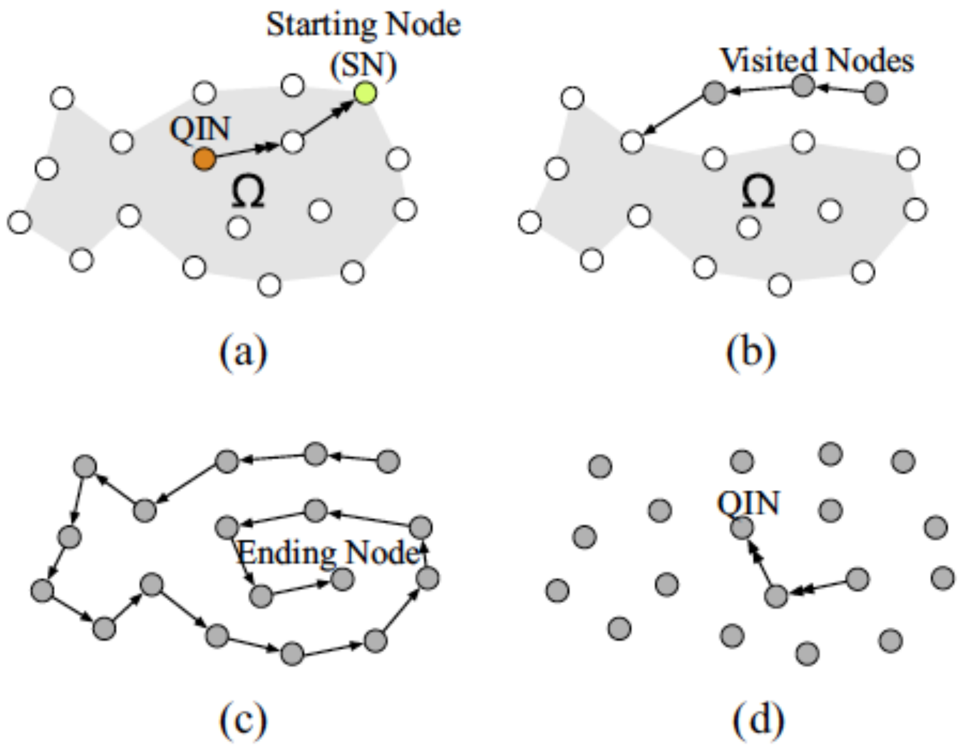


Fig. 3. PA overview.

Well suitable for dense and hole free topologies

Peeling Algorithme

Problem: unvisited region disconnectivity

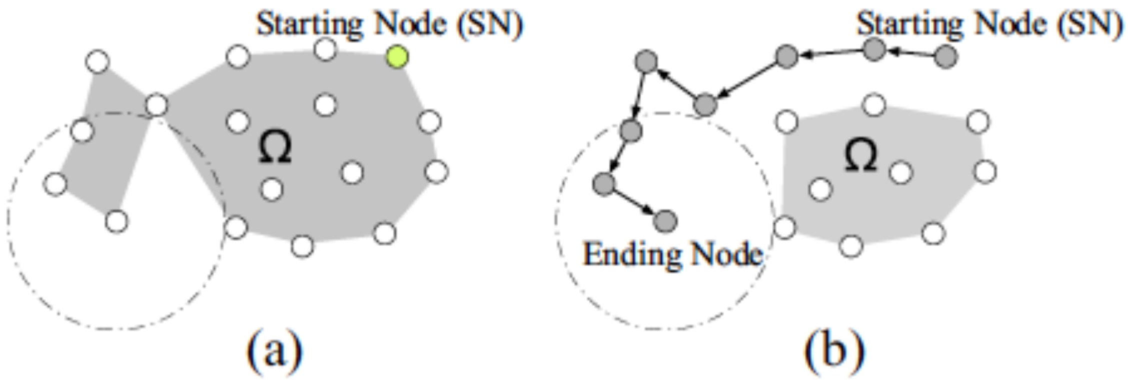
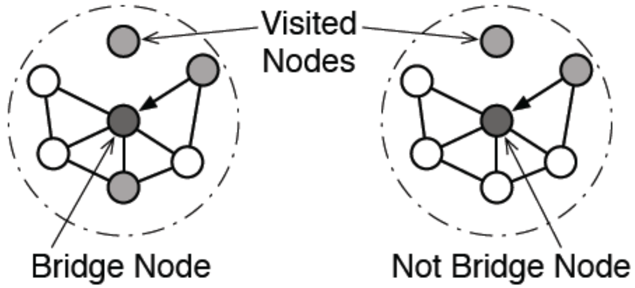


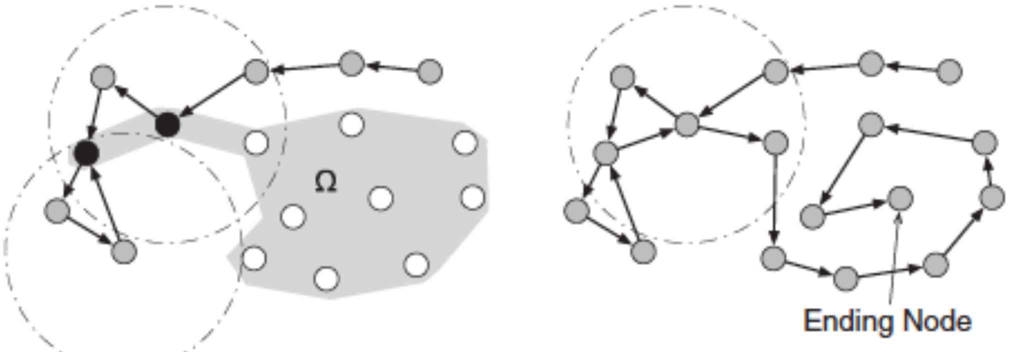
Fig. 4. (a): One node ensures Ω connectivity; (b): once this node is visited, Ω is partitioned, leading to unvisited nodes.

Peeling Algorithme

Solution: bridge node

Definition 6 (*BRidge Node*). A node is called Bridge Node and denoted by *BRN*, when it satisfies the following two conditions: (a) at least two of its unvisited or *BRN* neighbors cannot communicate and (b) none of the other unvisited or *BRN* neighbors are able to connect these two neighbors.

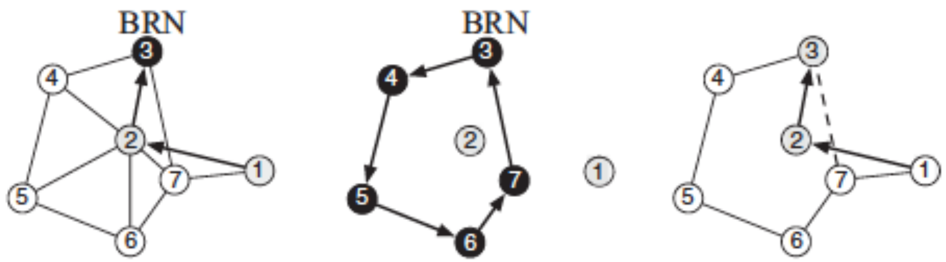




(a) (b)

Peeling Algorithme

Problem: artificial holes



(a) (b) (c)

Definition 7 (*Potential Boundary Node*). A node N_i is said to be a Potential Boundary Node (PBN) iff, when considering only its live neighbors (i.e., unvisited or BRNs), it is a boundary node per Definition 2.

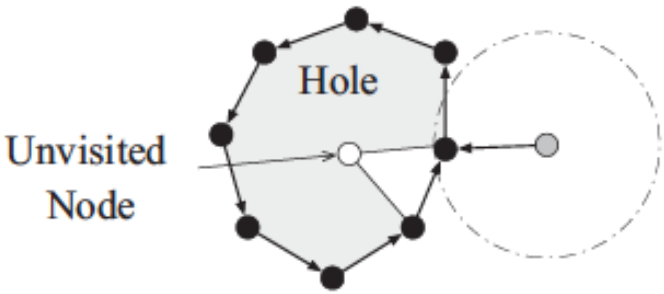
Solution: deactivated links

Based on $V_i(\Omega)$, the current node N_i can determine which links, among $V_i(\Omega)$'s links, are crossing the boundary of Ω. For instance, in our running example, N_2 can easily determine that $L_{\{7,3\}}$ is crossing the current Ω boundary. Hence, when a node N_i, upon receiving the peeling message from its previous hop, denoted by N_{prev}, detects itself as **not a PBN** and **there exist some links crossing the current Ω boundary**, it performs the following:

- It constructs two sets: (a) the first one contains all nodes, involved in the crossing links that are on the right side of the segment $[N_i, N_{prev}]$; (b) the second set is formed from the other nodes. In the example, the two sets are: $\{N_7\}$ and $\{N_3\}$.
- It sends the peeling message with this additional information about the two sets.

Peeling Algorithme

Hole's Problem:



Solution: breaking the hole

Definition 10 (*Hole Gate Node (HGN)*). We define the Hole Gate Node (HGN) of a hole as the first PHBN, belonging to this hole, that takes part in the peeling process.

The objective of the HGN is twofold: (a) it orients the peeling process toward the hole, in order to visit all nodes and (b) it must guarantee that the latter can get out of the hole. The unique way to meet these two requirements, while using a serial boundary traversal algorithm, is to deactivate some particular links in Ω. In other terms, we must modify the boundary of Ω, without altering its connectivity (i.e., all unvisited nodes of Ω must remain connected).

Peeling Algorithme

Solution: HGN

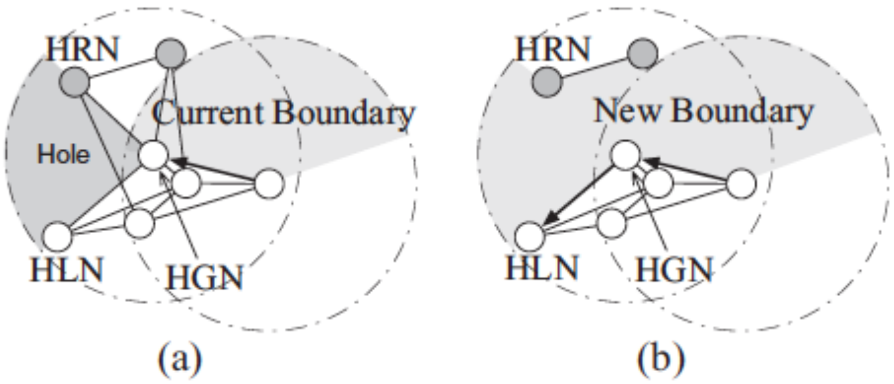


Fig. 10. Hole Gate Node (HGN) Rules: (a) before performing HGN rules and (b) after changing Ω boundary.

3.2.2. HGN rules

Once a node, receiving the peeling message from its previous node (N_{prev}), has defined itself as an HGN, it executes the following:

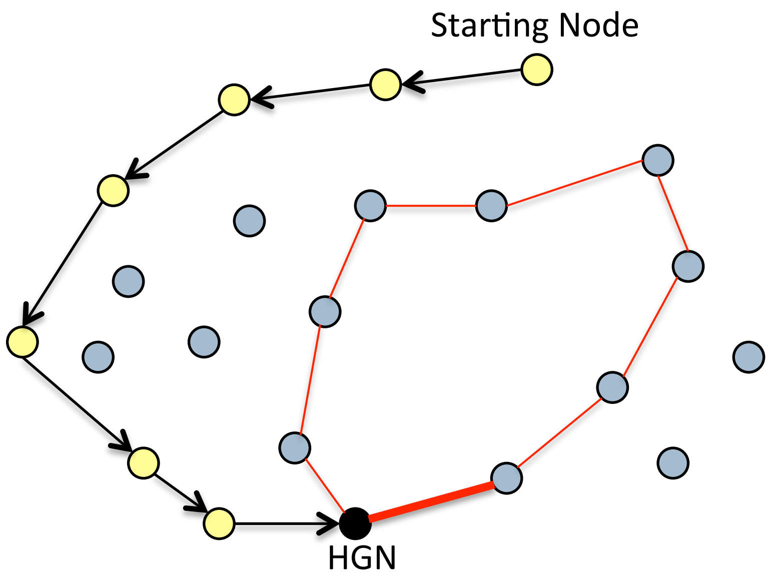
1. It creates two sets from its neighbors as follows:
   - **Front Set (FS)**: this first set contains all neighbors located in the sector with $\angle N_{prev}HGNHLN$ as its central angle. In the example of Fig. 10, gray nodes are in this set including HRN.
   - **Back Set (BS)**: the second set is composed of the rest of the neighbors, including the HGN itself and its HLN. In the example of Fig. 10, all green colored nodes are in this set.
2. It virtually deactivates its link with every node in FS. This means that the HGN will not consider them as its neighbors for this query. Formally, the set $\mathcal{DL} = \{L_{\{HGN,i\}} | N_i \in FS_{(HGN)}\}$ is removed from $\mathcal{L}$ for this query.
3. The HGN initializes a message which contains: (a) its identity, as an HGN of this hole; and (b) the two sets $FS_{(HGN)}$ and $BS_{(HGN)}$, previously constructed.
4. It broadcasts this message to its neighbors.

Upon receiving the HGN message, each neighbor will perform the following steps:

1. Determine to which set it belongs: $FS_{(HGN)}$ or $BS_{(HGN)}$.
2. Based on its membership to one of these sets, it virtually deactivates, as done previously by the HGN, its link with each node belonging to the other set, whenever such a link exists.

Peeling Algorithme

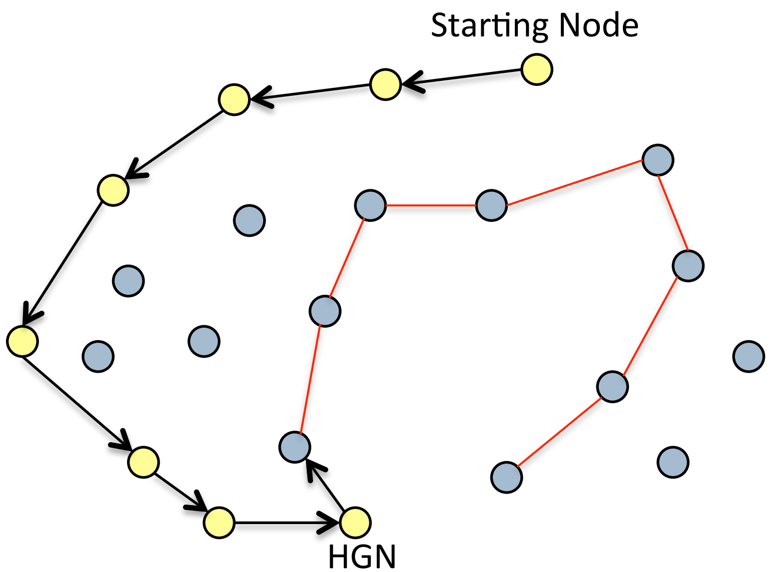
Solution: breaking holes



Peeling Algorithme

Solution: breaking holes

Definition 6. *(Hole Gate Node (HGN))*
For each hole H, we define its Hole Gate Node (HGN) (HGN $\in H$) as the first node that holds the peeling process.



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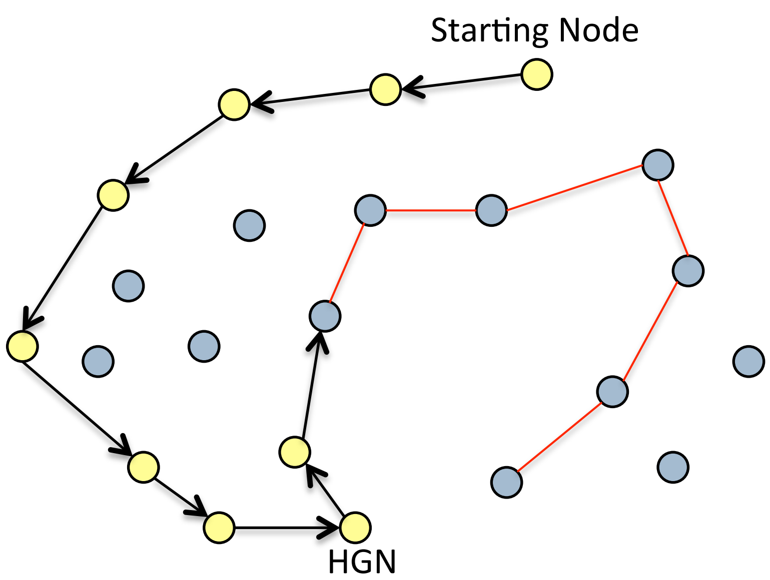

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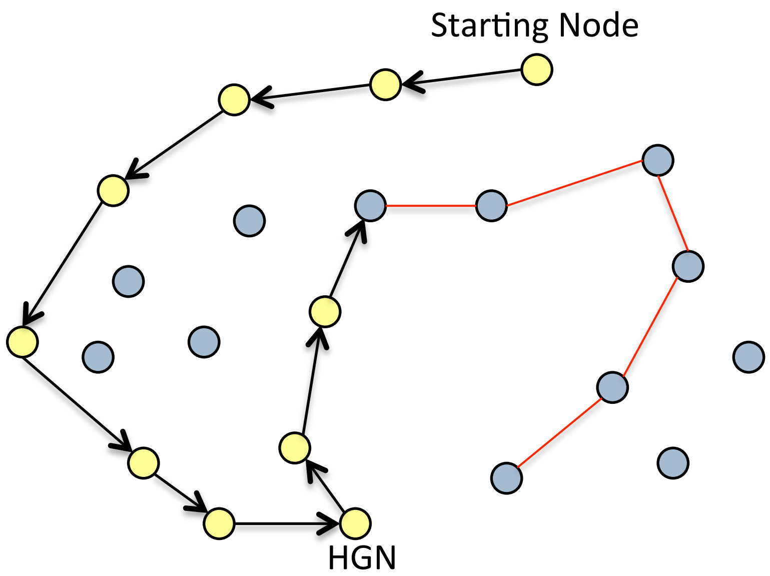

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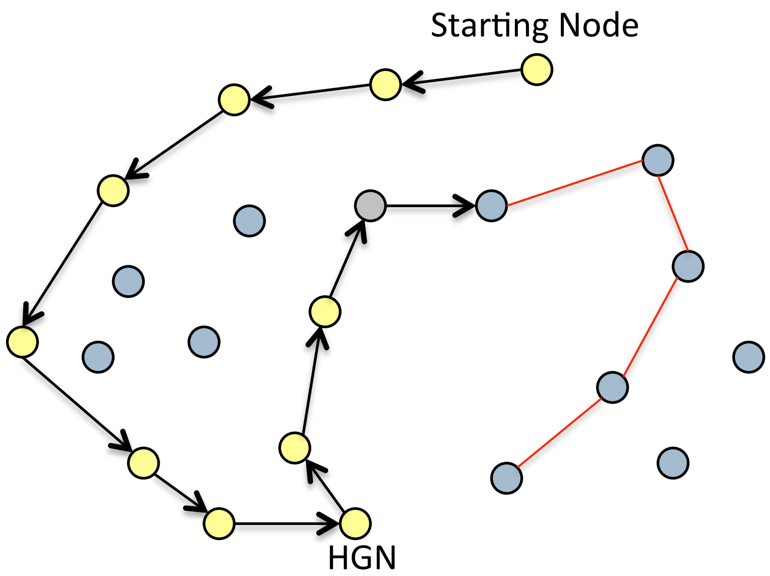

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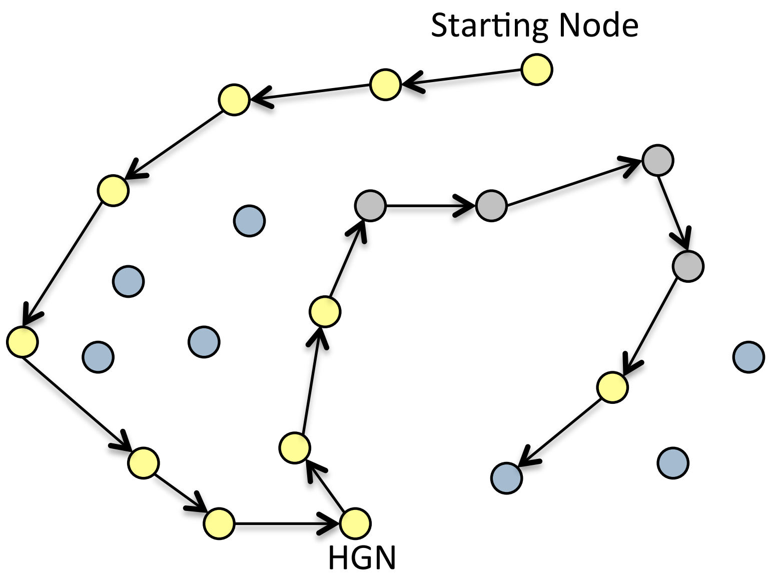

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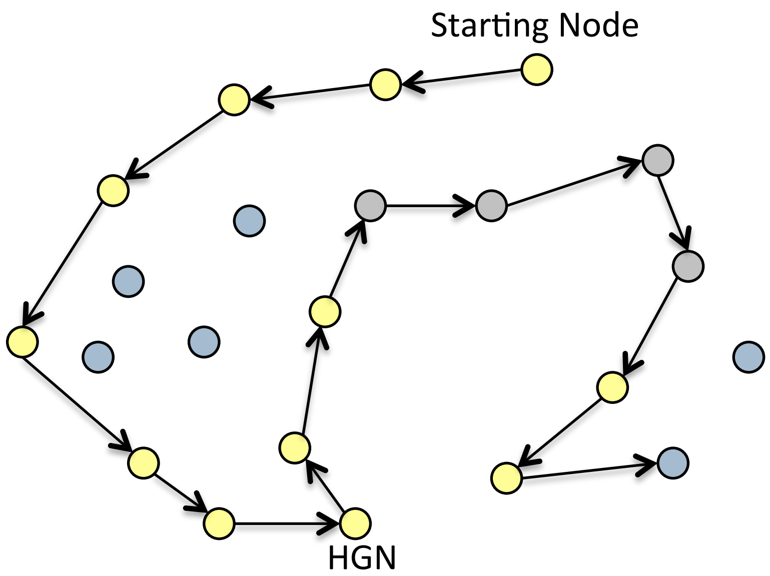

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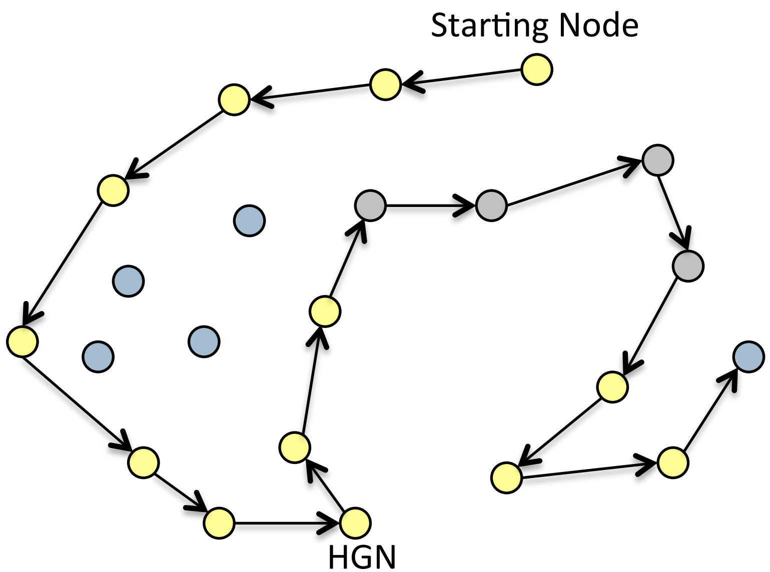

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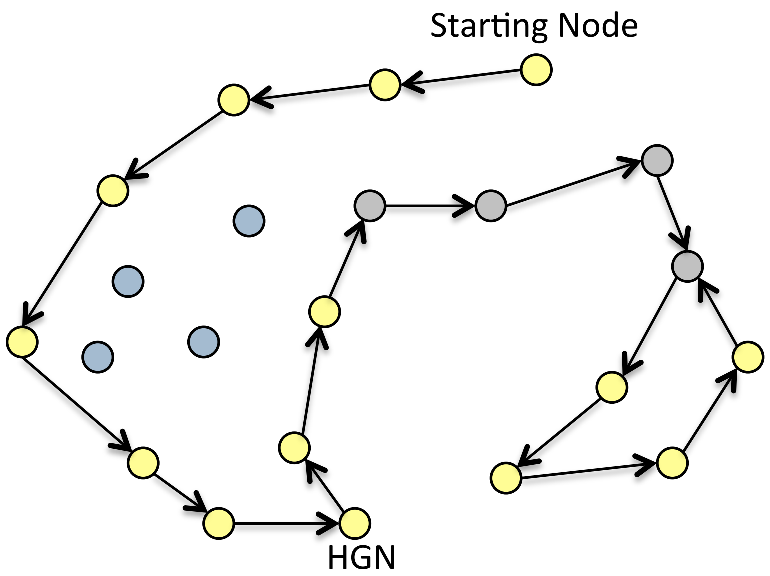

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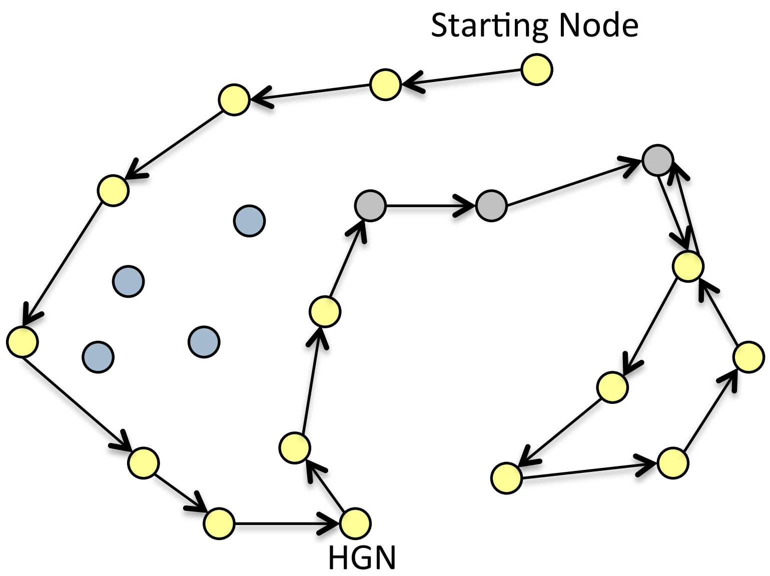

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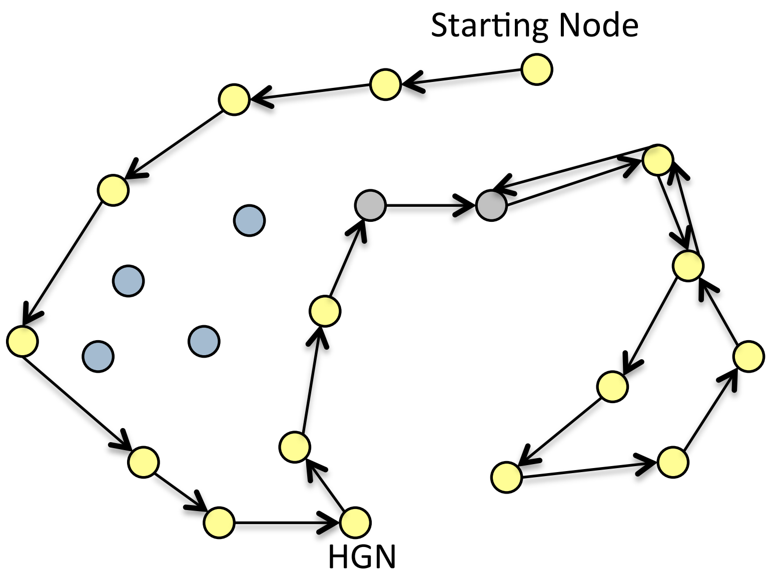

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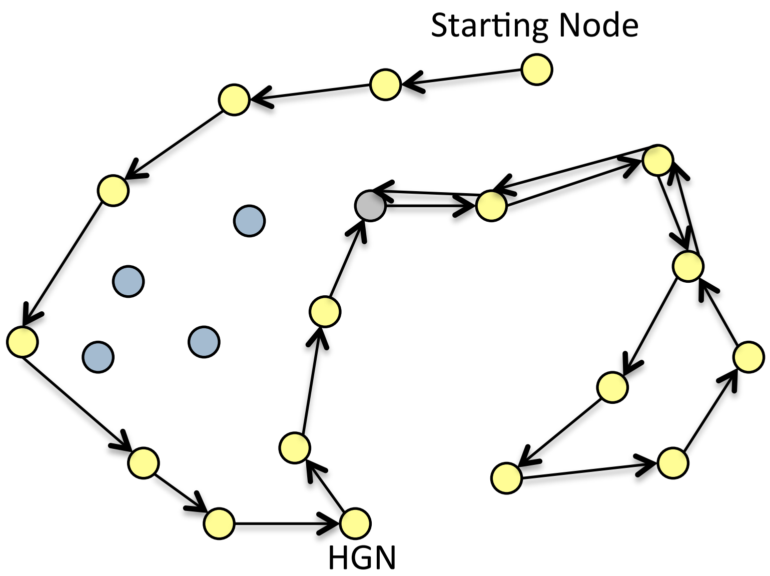

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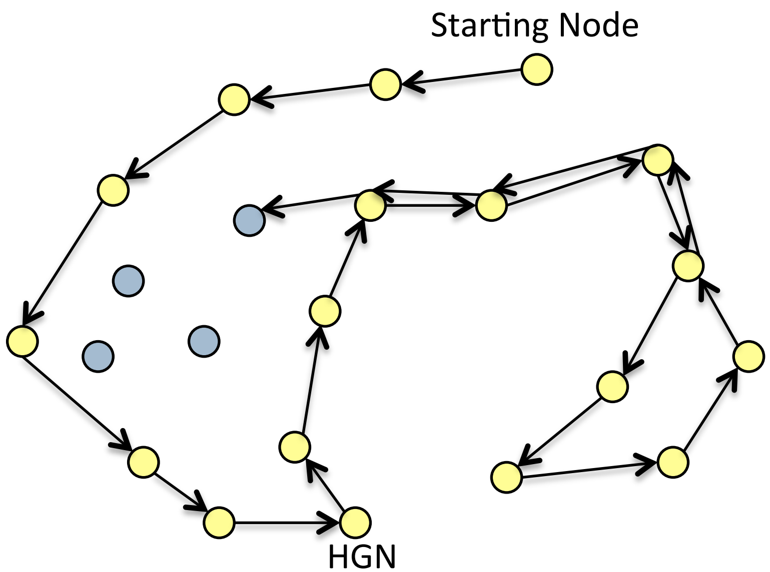

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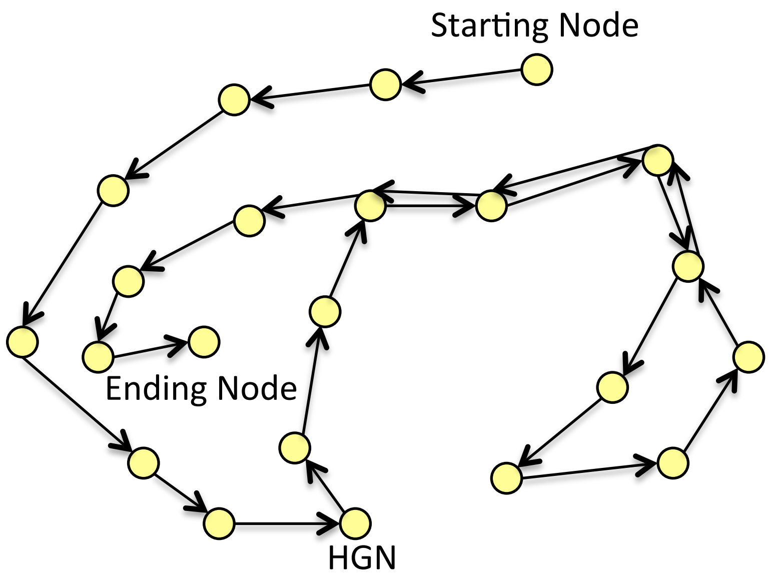
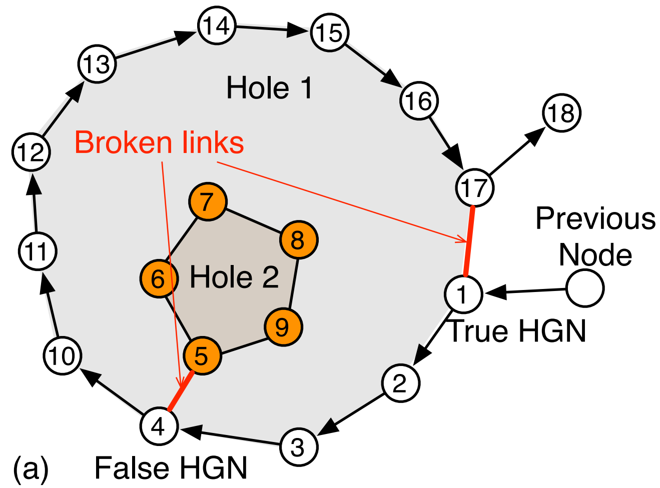
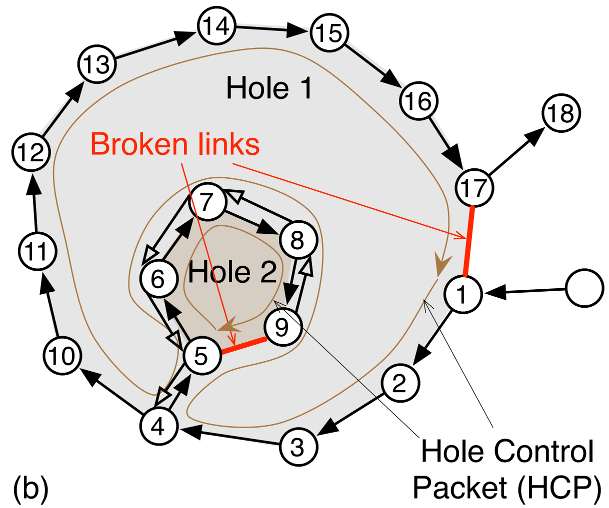


Peeling Algorithme

Problem: imbricated holes (False HGN)



Solution: Hole Control Packet launched by the HGN



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Peeling Algorithme

- Starting Node Detection Process
- Identifying NBNs set

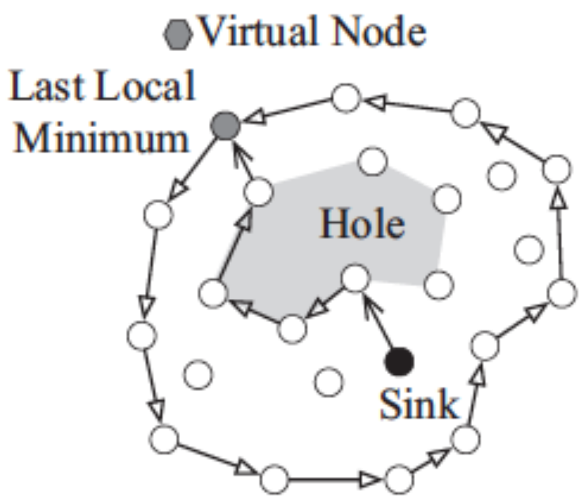

Fig. 12. Network boundary nodes detection process.

A. Mostefaoui, M. Melkemi and A. Boukerche "*Efficient Algorithm for Serial Data Fusion in Wireless Sensor Networks.*" In the 16th ACM International Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems, MSWiM '13, Pages 181--188, Barcelone, Nov. 2013

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Proof of correctness

- Objective: prove that PA guaranties all nodes contribution in the query (i.e., visits all nodes) whatever the configuration of the network is.

- Two steps:
  - Step 1: prove that PA terminates (free of looping).
  - Step 2: prove that the generated sequence of visited nodes contains all nodes of the network.

Proof of correctness

Step 1:

Formally, PA constructs iteratively the set Ω_i, following the recurrent relationship defined as follows:

$$\begin{cases} \Omega_0 = \mathcal{N} \\ \Omega_{i+1} = \Omega_i - \{P_i\} \end{cases}$$

Where P_i is the first visited node which is not a bridge node during the scan of Ω_i.

Proof of correctness

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Where P_i is the first visited node which is not a bridge node during the scan of Ω_i.

Lemma 1.
At each iteration i, PA visits a no bridge node P_i (i.e., P_i exists).

Proof of correctness

Step 1:

Formally, PA constructs iteratively the set Ω_i, following the recurrent relationship defined as follows:

$$\begin{cases} \Omega_0 = \mathcal{N} \\ \Omega_{i+1} = \Omega_i - \{P_i\} \end{cases}$$

Where P_i is the first visited node which is not a bridge node during the scan of Ω_i.

Lemma 1.
At each iteration i, PA visits a no bridge node P_i (i.e., P_i exists).

Theorem 2.
PA generates a finite sequence $\mathcal{P} = \bigcup_{i=0}^{k} P_i$ (i.e., PA terminates).

Proof of correctness

Step 2:

Lemma 2.
At each iteration i, node $P_i \in B(\Omega_i)$ i.e., P_i is on the boundary of the current sub-network Ω_i.

Theorem 3.
The sequence $\mathcal{P}$ generated by PA contains all nodes of the network (i.e $\mathcal{P} = \mathcal{N}$).

Outline

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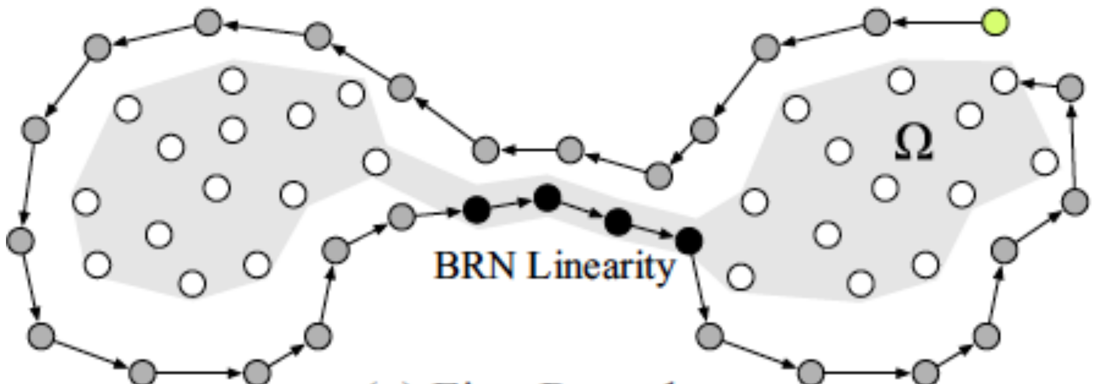
Enhanced PA

Linearity phenomenon

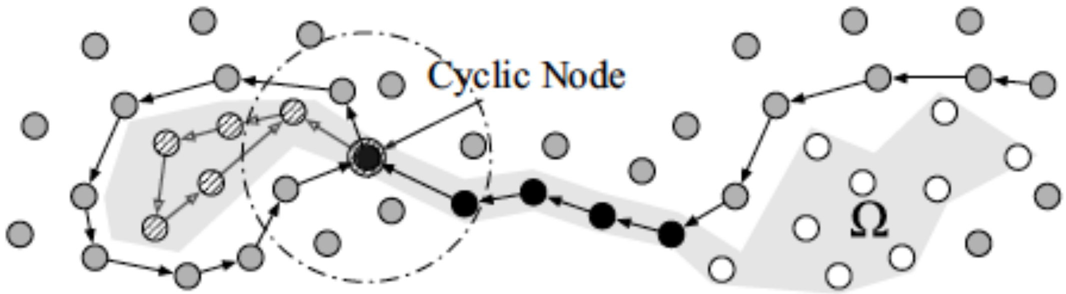


(a) First Round

Enhanced PA

Cyclic nodes

Definition 12 (*Cyclic Nodes (CN)*). A node N_i becomes a **Cyclic Node**, denoted by CN_i, iff it conforms to the two following conditions: (a) it is a bridge node (BRN) and (b) it receives the peeling message from two different directions.



(b) Second Round

Outline

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Performance Evaluation

- Compared Approaches:
  - Centralized approach
  - Iterative approach
  - Depth First Approach
  - PA
  - EPA

- Metrics:
  - Communication Efficiency (# hops)
  - Consumed Energy,
  - Query Time-To-End (i.e., query responsiveness)

Performance Evaluation

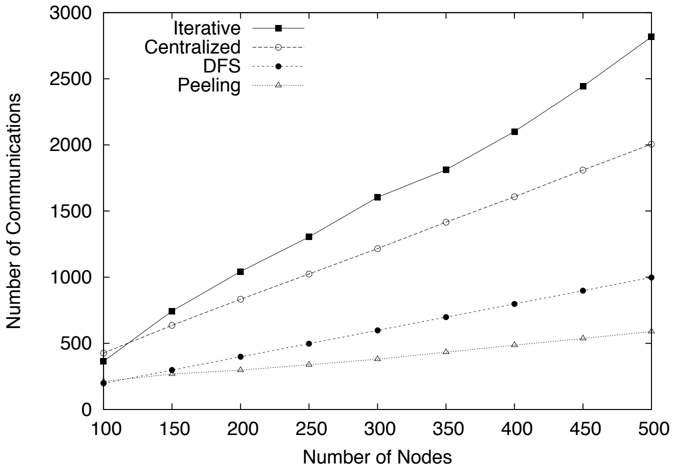
- Settings :

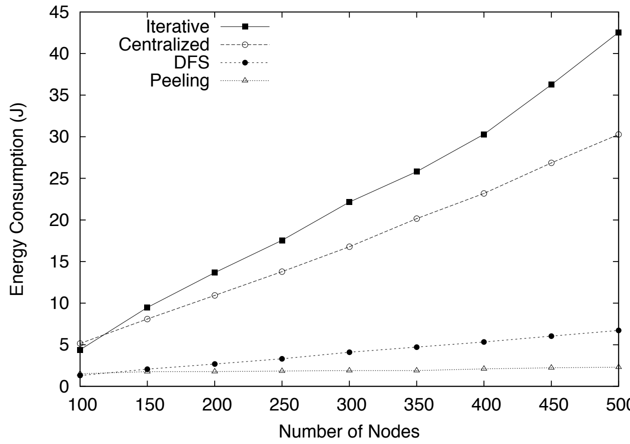
Table 2
Simulation parameters.

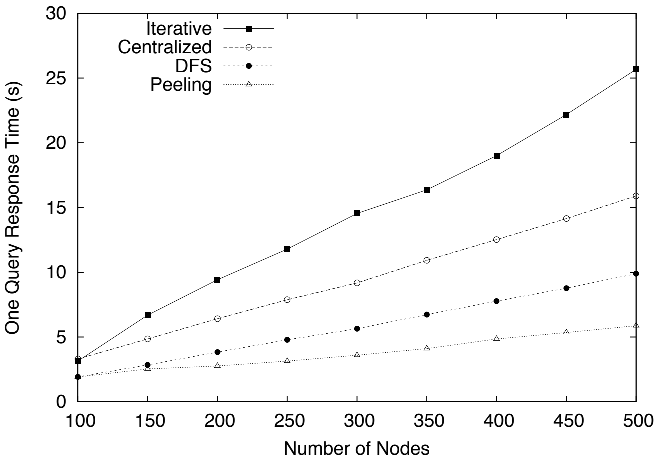
Parameter	Value(s)
Network area (m^2)	1000×1000
Transmission range (m)	150
Node distribution	Uniform
Number of nodes	100, 150, 200, ..., 500
QIN location	Random
Packet size	50 Bytes
Sensed values interval	[0,0.4]
Convergence threshold for iterative approach	10^{-2}

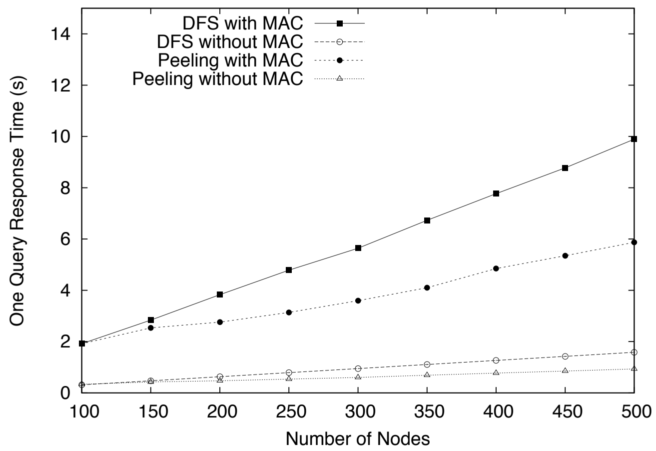
Performance Evaluation

- Single query performance:



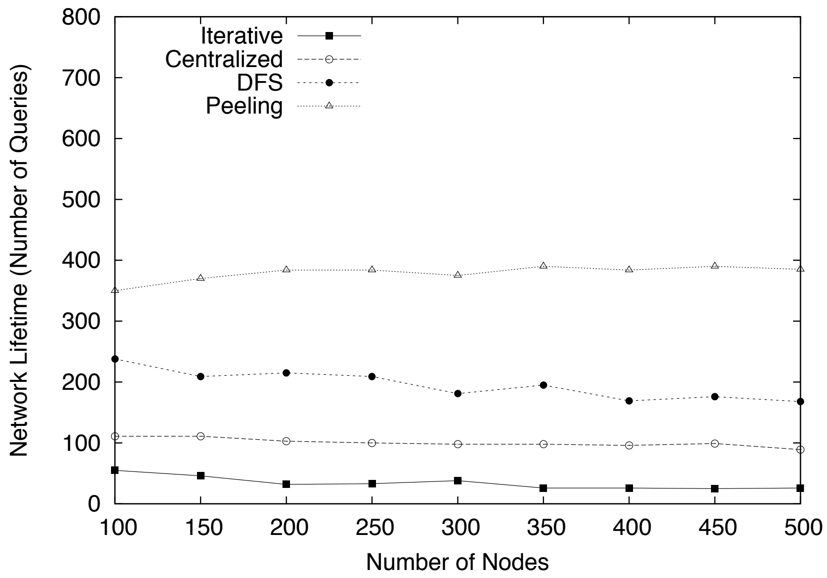






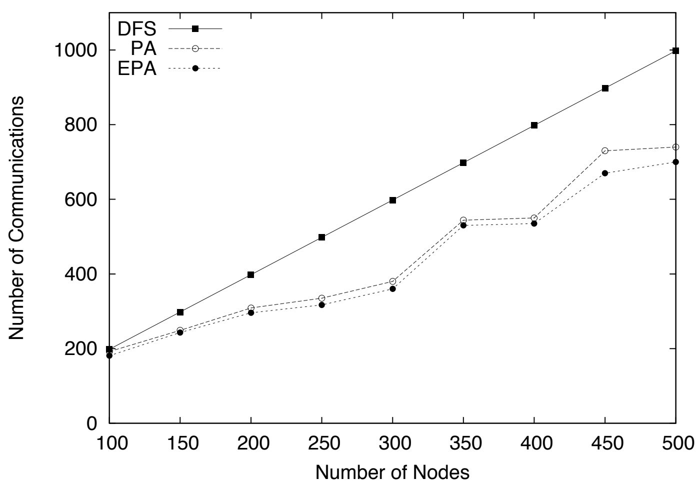
Performance Evaluation

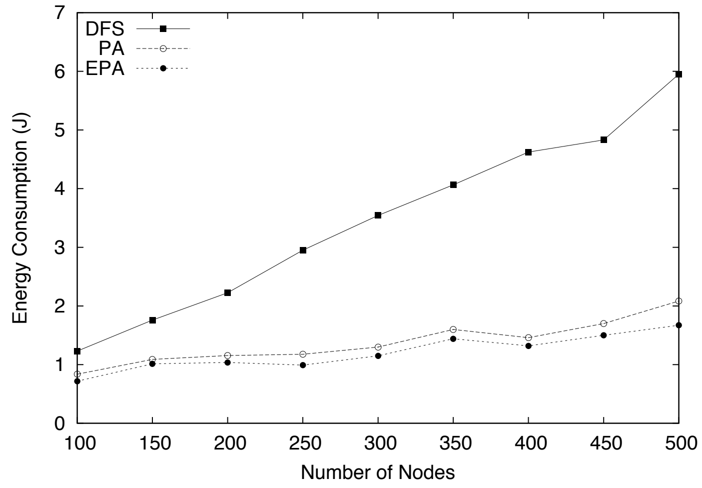
- Multiple queries:

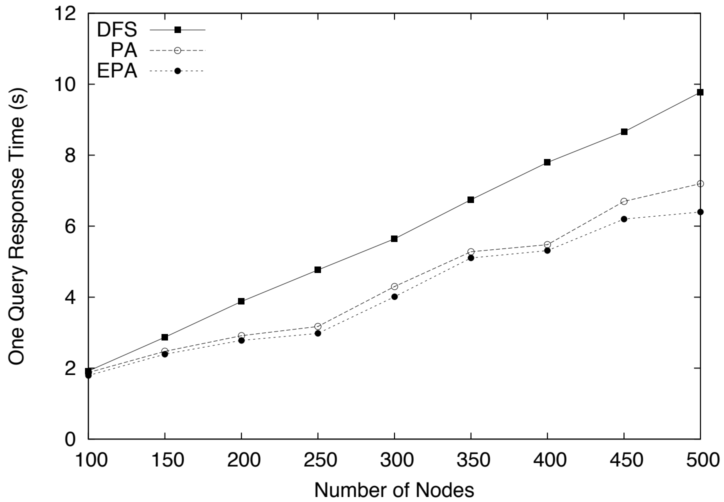


Performance Evaluation

- EPA performance:







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Conclusion and Future Work

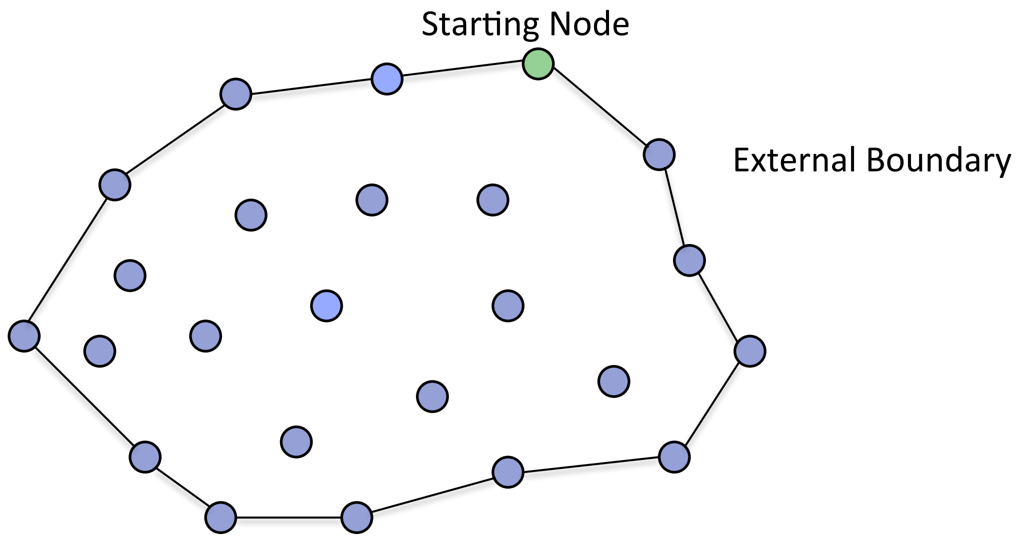
- Efficient and Scalable serial approach for data fusion in WSN.
- Theoretically proven to ensure query completeness (i.e., visiting all nodes) in any network configuration.
- Suitable for dense and large scale deployments.
- Still vulnerable to link and nodes failures

Merci pour votre attention…

Questions?

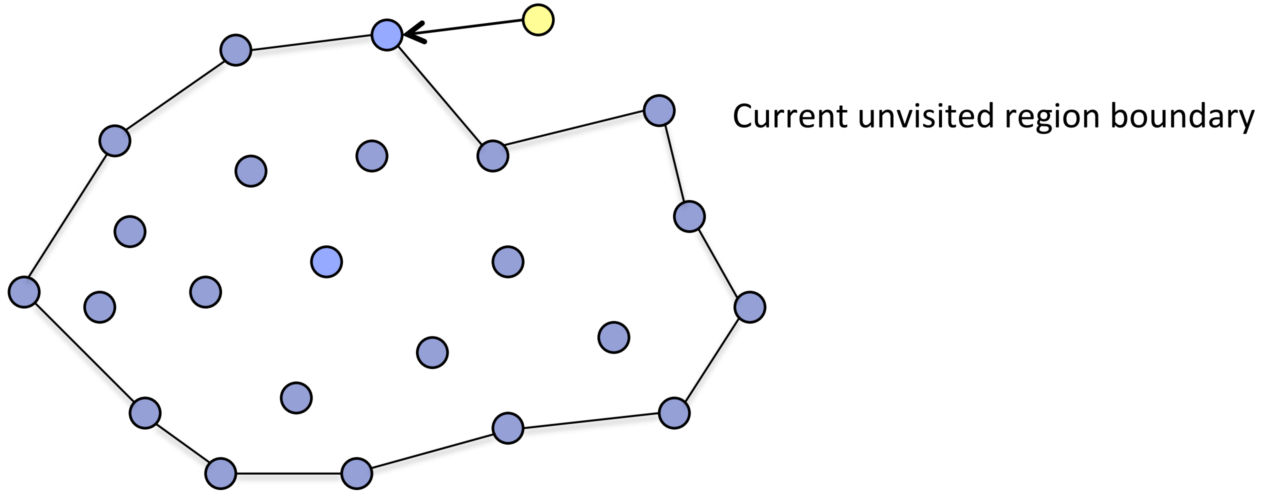
Peeling Algorithme

Overview:



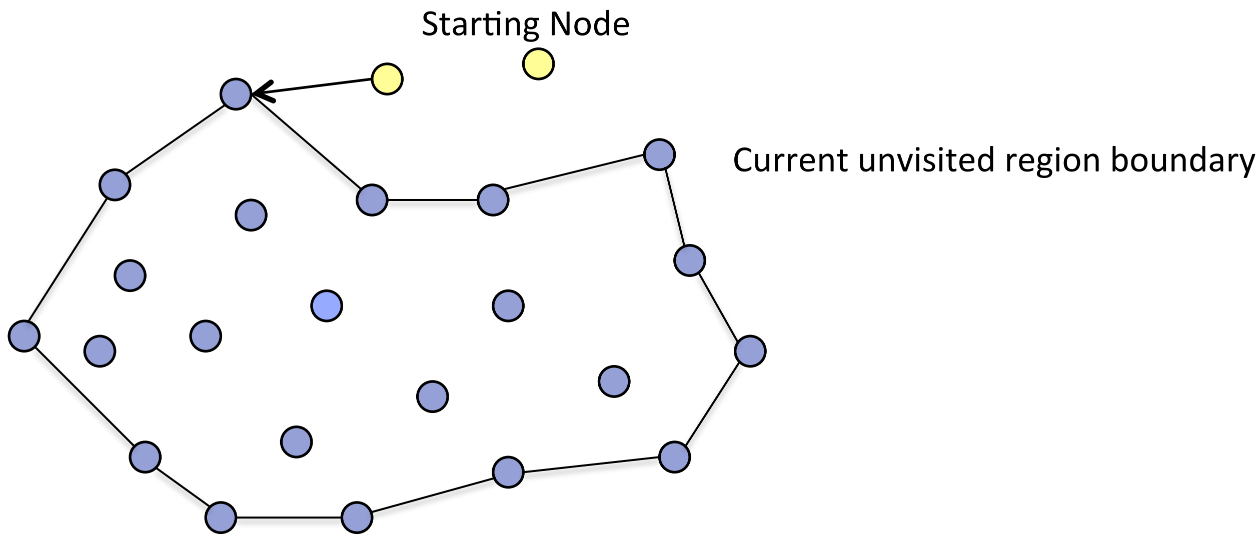
Peeling Algorithme

Overview:



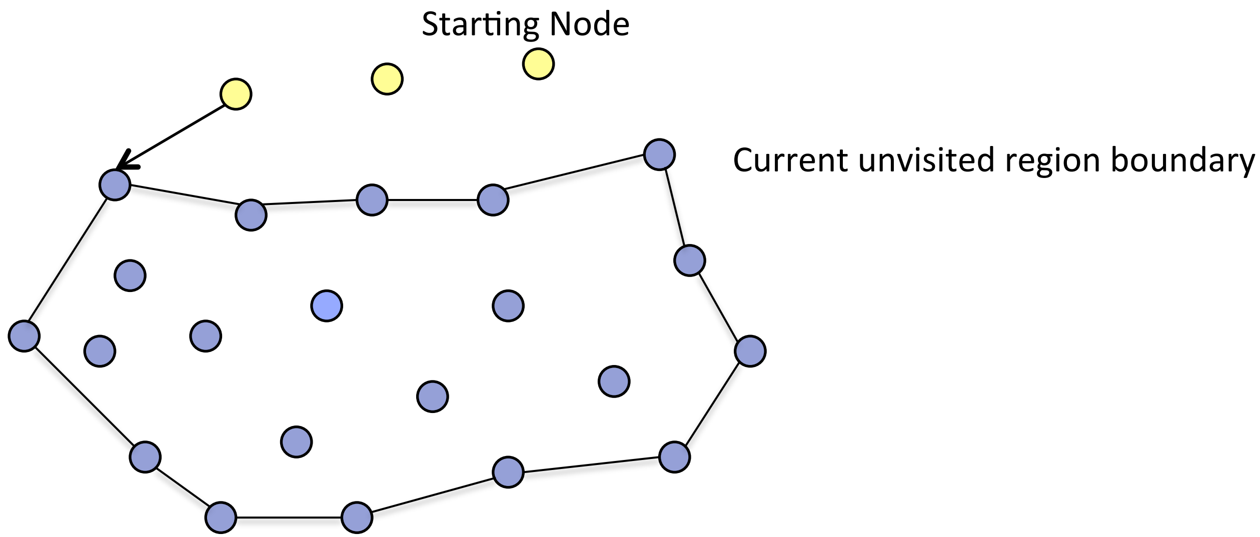
Peeling Algorithme

Overview:



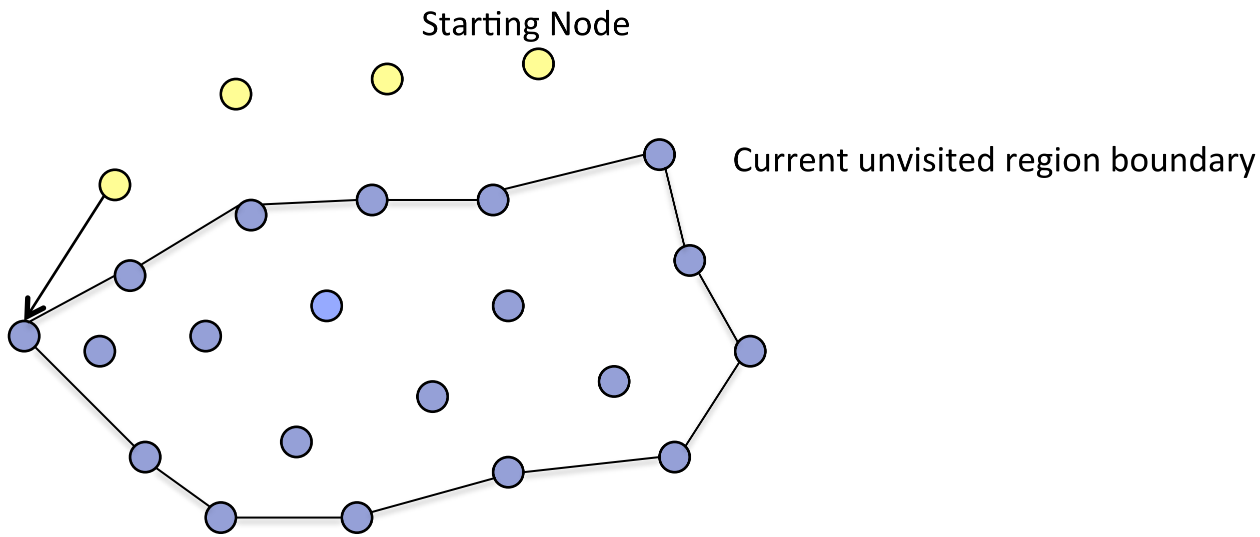
Peeling Algorithme

Overview:



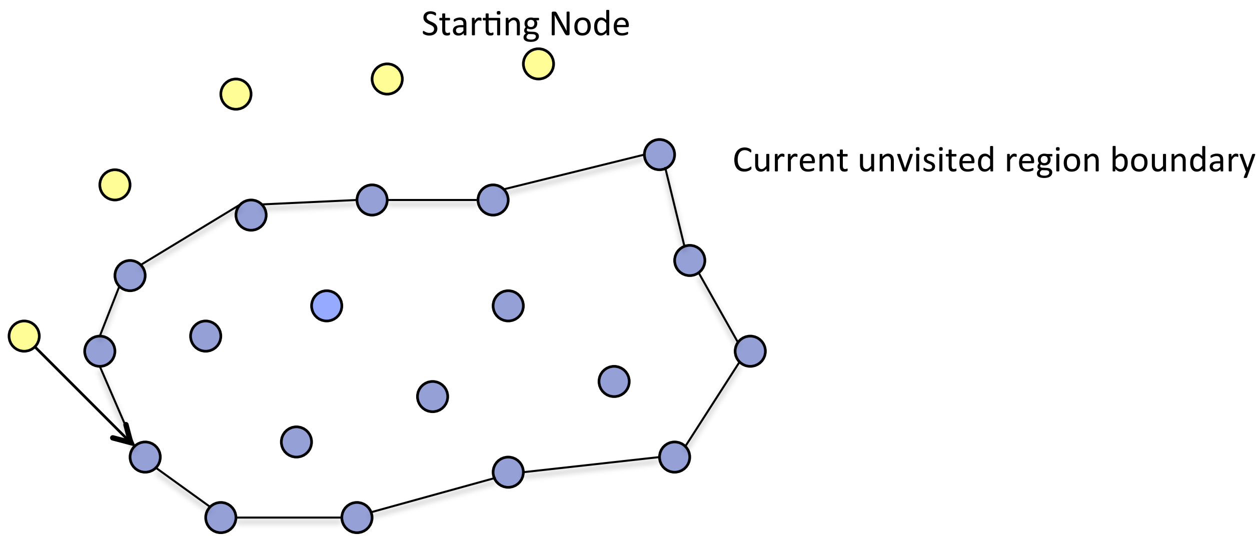
Peeling Algorithme

Overview:



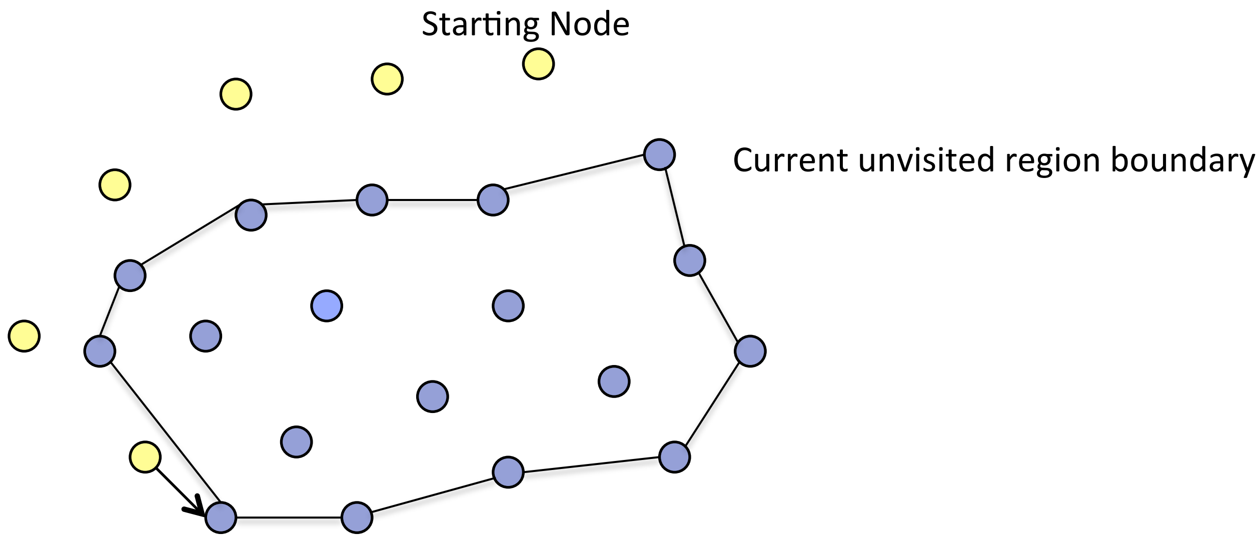
Peeling Algorithme

Overview:



Peeling Algorithme

Overview:



Peeling Algorithme

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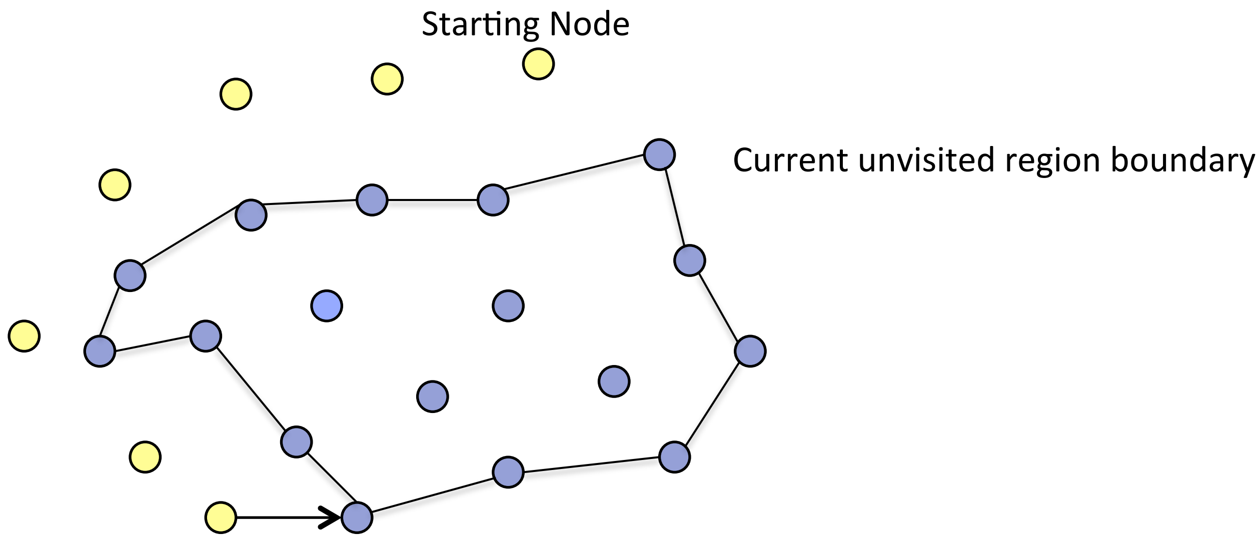
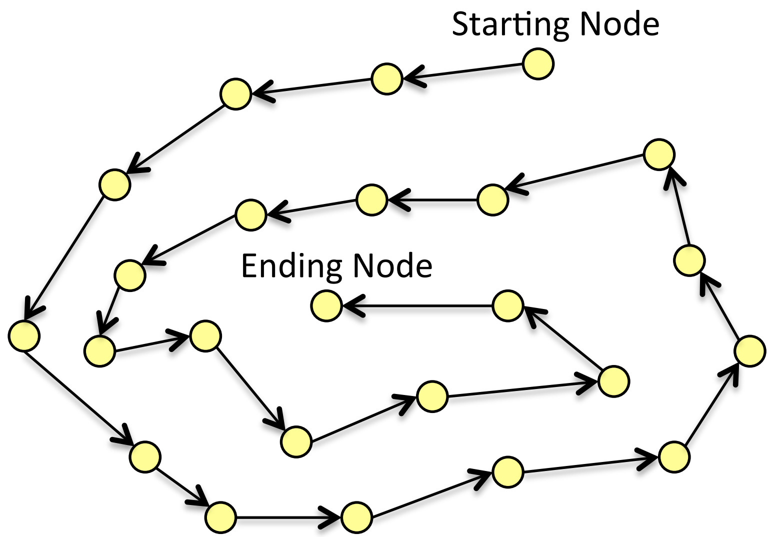


Peeling Algorithme

Overview:



Well suitable for dense and hole free topologies