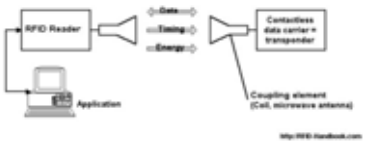
Redundant Reader Problem



IM PHD Student
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Current developing of RFID

	Reader	WReader
Tag	RFID	WRFID
STag	SRFID	SWRFID

- Reader
  - Traditional
  - Wireless
- Tag
  - Information repository
    - Read-only, read-writable,
  - Information retrieval
    - Sensor capability

Simple Ad hoc Hybrid

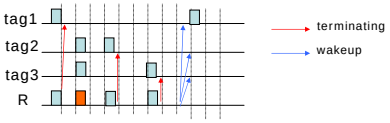
Network complexity

Collision Problems

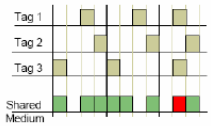
- Collision problems of RFID are
  - Reader-reader collision (RR)
  - Reader-tag collision (RT)
- Anti-collision algorithm for RR
  - Centralize
  - Distributed
- Anti-collision algorithm for RT
  - Slotted aloha (ISO 18000-3)
  - Frame slotted aloha
  - Tree walking algorithm, TWA (EPC global)

Tag Collision Control

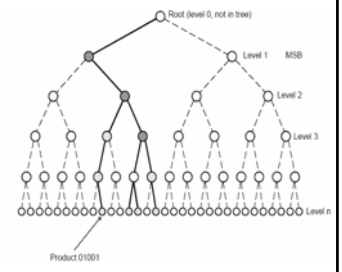
- Slotted Aloha with additional controls



- Frame Slotted Aloha



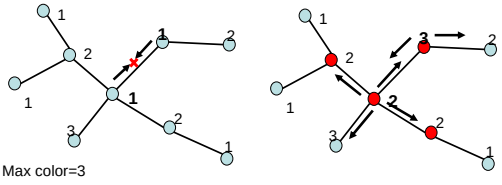
- Tree walking algorithm (TWA)
- The tree depth must be small as possible. It means that tree only keep the most important information of the tag id, while the rest of bits will be retrieved from the network



EPC 900 MHz Class 0 Radio Frequency (RF) Identification Tag Specification

Anti-collision algorithm for reader

- Colorwave†: A distributed algorithm for reader collision problem



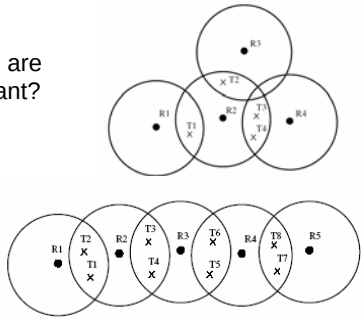
Max color=3

† Colorwave: an anticollision algorithm for the reader collision problem (RCP), IEEE International Conference on Communications, 2003. ICC '03., by James Waldrop, Daniel W. Engels, Sanjay E. arma

- *Redundant Reader Elimination in RFID Systems*, Bogdan Carbunar et al. To be presented in IEEE SECON 2005, 28-9-2005
- The redundant reader elimination problem is:
  - To find the minimum number of reader that cover all RFID tags and to maximize the number of reader that can be simultaneously deactivated
- The formal definition:
  - Given a set of tags and a set of readers covering all tags, find the minimum cardinality subset of RFID readers, covering all tags

Redundant reader problem

- Which readers are redundant?



- The reader redundant elimination problem is NP-hard
- Proves its NP-hardness by using the polynomial time reduction method from a known NP-hard problem to redundant reader problem
- The geometric disk cover (DC) problem which is known as NP-hard problem can be used to the reduction
  - Input of DC: a set of m points, a value R
  - Output of DC: minimum number of disks of radius R covering all m points

- Lemma1
  - Given a set of n points, p1, p2…pn, placed in side a circle of radius R, there exists a subset of 3 of the n points, pi, pj, pk, such that all n points are placed inside circle of C(Oijk, R). Oijk denotes mass center of pi, pj, pk

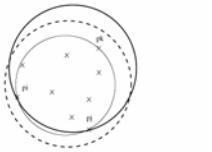


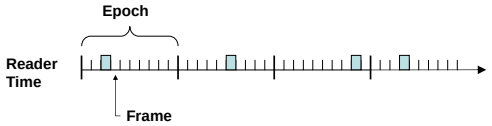
Fig. 2. Set of points covered by a circle of radius R, shown with an interrupted perimeter. There is a circle of radius R going through points p_i and p_j and covering all the other points. Shrink this circle until it first touches one more point, p_k. The resulting circle, has radius less than or equal to R.

Proof of NP-hard

- Add a disk of radius R centered at each point in the input set of DC
- For all combinations of 3 points of the input set of DC, add a disk of radius R, centered at the mass center of the 3 points
- S denotes the set of all disk created. S covers all input points of DC; DC⊆S; the disks that form the solution for the DC are contained in S
- The reduction requires $O(m^3)$
- If a polynomial time solution for redundant reader problem exists, then a polynomial time solution for DC problem exists

Reader Collision Avoidance (RCA)

- RCA is declared to be a randomized, distributed and local solution to RR, and requires no direct communication between readers (as compare to Colorwave)
- The basic idea of RCA is similar to frame slotted aloha
  - RCA is presented in the context of TWA
  - The reader sends a broadcast query containing a certain prefix expected to match the identifiers of tags in its interrogation zone.
  - When there is no answer from tags, the reader backs off for a random number of time frames and repeats the query

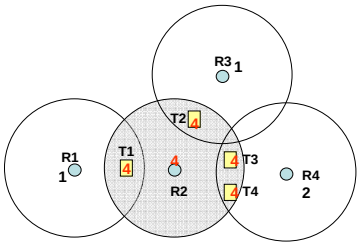


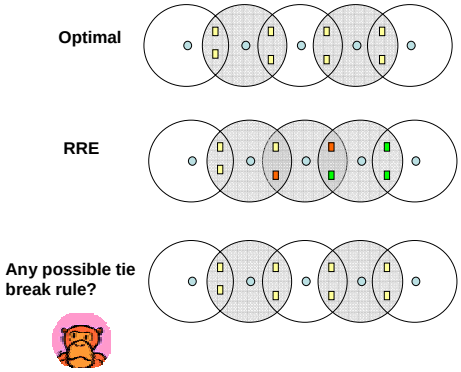
- In each epoch, the reader randomly picks a frame and sends out the query. If no tag answer is received, the reader repeats the query at next epoch
- Let ϕ = total number of reader, τ = number of frames per epoch, γ = total number of tags. When $\tau = \gamma$, If a query is not answered O(log ϕ) times, there are no tags matching the query†.

†:Murali k. Ramanathan, Bogdan Carbunar, Suresh Jagannathan, and Ananth Grama Reader collision avoidance in rfid systems, Technical report 05-014, Purdue University, 2005.

The redundant reader elimination (RRE) algorithm

- Each reader must run RCA first to detect all tags within its interrogation zone. After running RCA, reader gets the tag count
- Assumption: tag must be writable
- RRE
  - Stage 1: Each reader attempts to write its tag count along with its identifier to the tag. An RFID tag only stores the highest value. After O(log ϕ) epochs, each tag stores the largest number of an reader along with its id situated in its vicinity
  - Stage 2: reader queries each of its covered tags and read the id of the tag's holder. A reader locks no tag can be safety turned off



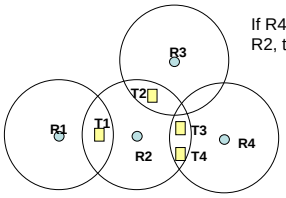


Discussion

- Synchronization
- Adaptivity

Discussion

- The synchronization problem



If R4 complete RCA and RRE before R2, then R4 may decide to stay in active

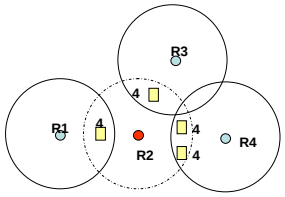
- There must be a synchronization mechanism In some way

Proposed method to synchronization

- Active reader maintains a list of locked tags
- Active reader passively listens for tag responses to queries initiated by other reader
- When reader R receives <Rx, Ty, C>, indicates that tag Ty is hold by Rx with count value C, if C is larger than its own count, R removes Ty from the list
- R becomes redundant when list is empty

Discussion

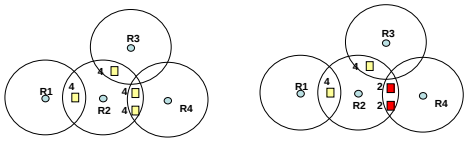
- Adaptivity for failure consideration
  - If active reader fails, some tags will leave to be undiscovered
- One possible solution the failure of reader
  - Inactive reader periodically re-activates to execute RRE?



R1, R3, R4 will not take over even R2 failed because all tags keep R2's count (4)

Proposed method to adaptivity

- Tag's counter value can be reset to 0
  - Every reader (both active and inactive) execute RCA periodically every T time units to rediscover its tags and reset tag count to 0
  - After RCA, reader execute RRE to set tag count
- Question: R4 reset tag count which previously set by R2



Proposed method to adaptivity

- Proposed solution
  - To set T of each reader to be inversely proportional to the tag count of the reader
  - For example, T_{R2}=1/4, T_{R4}=1/2, T_{R1}= T_{R3}= 1
  - R2 will execute this procedure more often then others
- Another proposed solution
  - Have timers on tag. Tag may store count only for a period of time
  - Drawback
    - For the timer: tag is more complex → Is the power of passive tag enough?

Thank you