Efficient Distributed Medium Access Arbitration for Multi-Channel Wireless Sensor Network

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outline

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- The Architecture and Operational Model
- Distributed Medium Access Arbitration
  - Intra-cell communication phase
  - Inter-cell communication phase
- Experimental Validation
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Introduction

- An efficient MAC layer protocol for WSNs should have the following design attributed

1. The protocol should be scalable since most applications of sensor networks involve a large set of sensor nodes.
2. Collisions among the transmissions of various nodes should be avoided.

Introduction

3. Idle mode of operation and transmission overhearing among sensors waste energy and thus should be minimized.
4. The protocol should not be contention-based. Control packets overhead and active sensing of the medium, typically performed by contention-based protocols, are inefficient in terms of energy consumption. In addition, the data collection latency tends to be unpredictable in such case.

Introduction

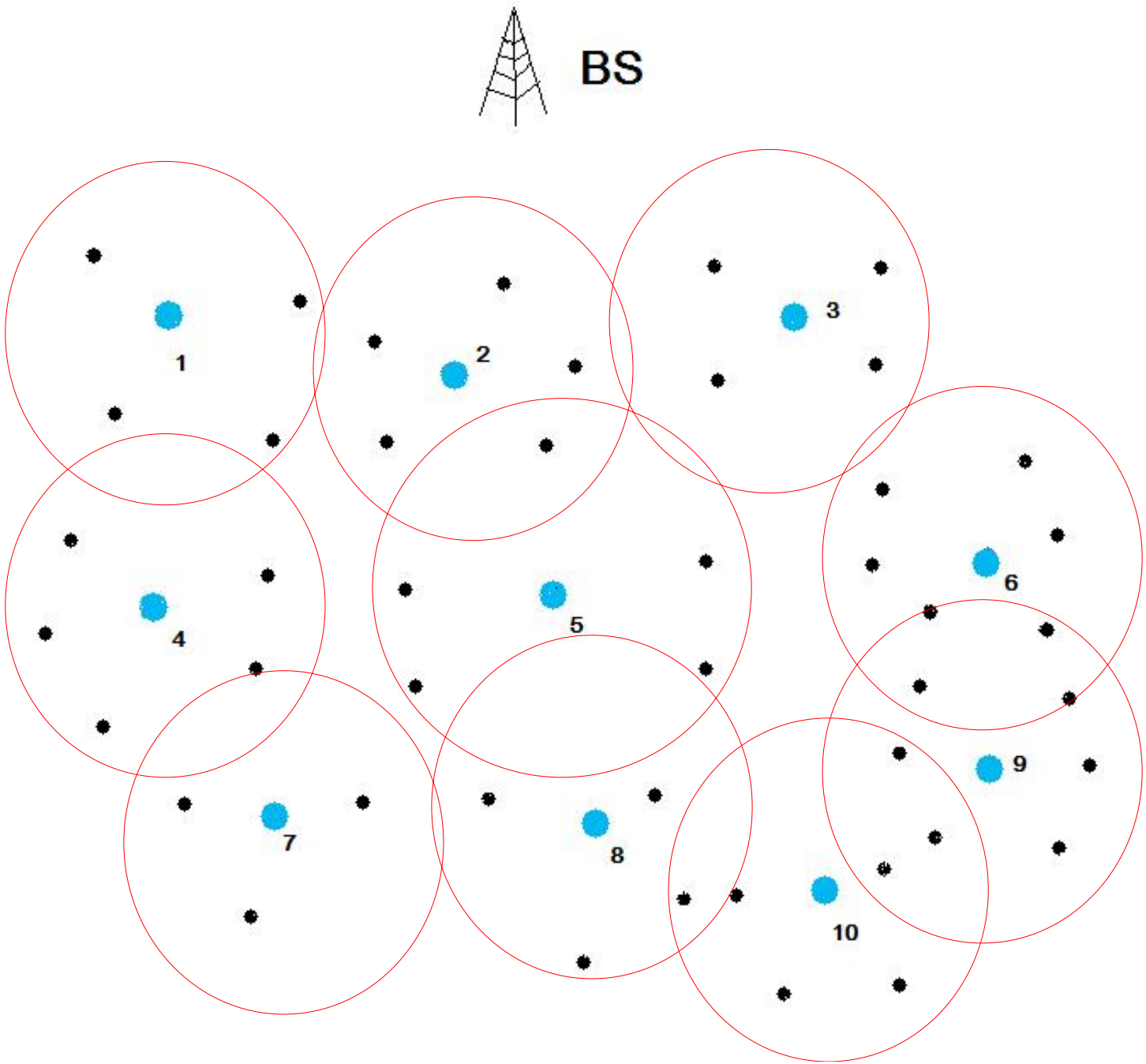
- In this paper we strive to support the scalability, energy efficiency and responsiveness goals at the MAC layer in wireless sensor network .

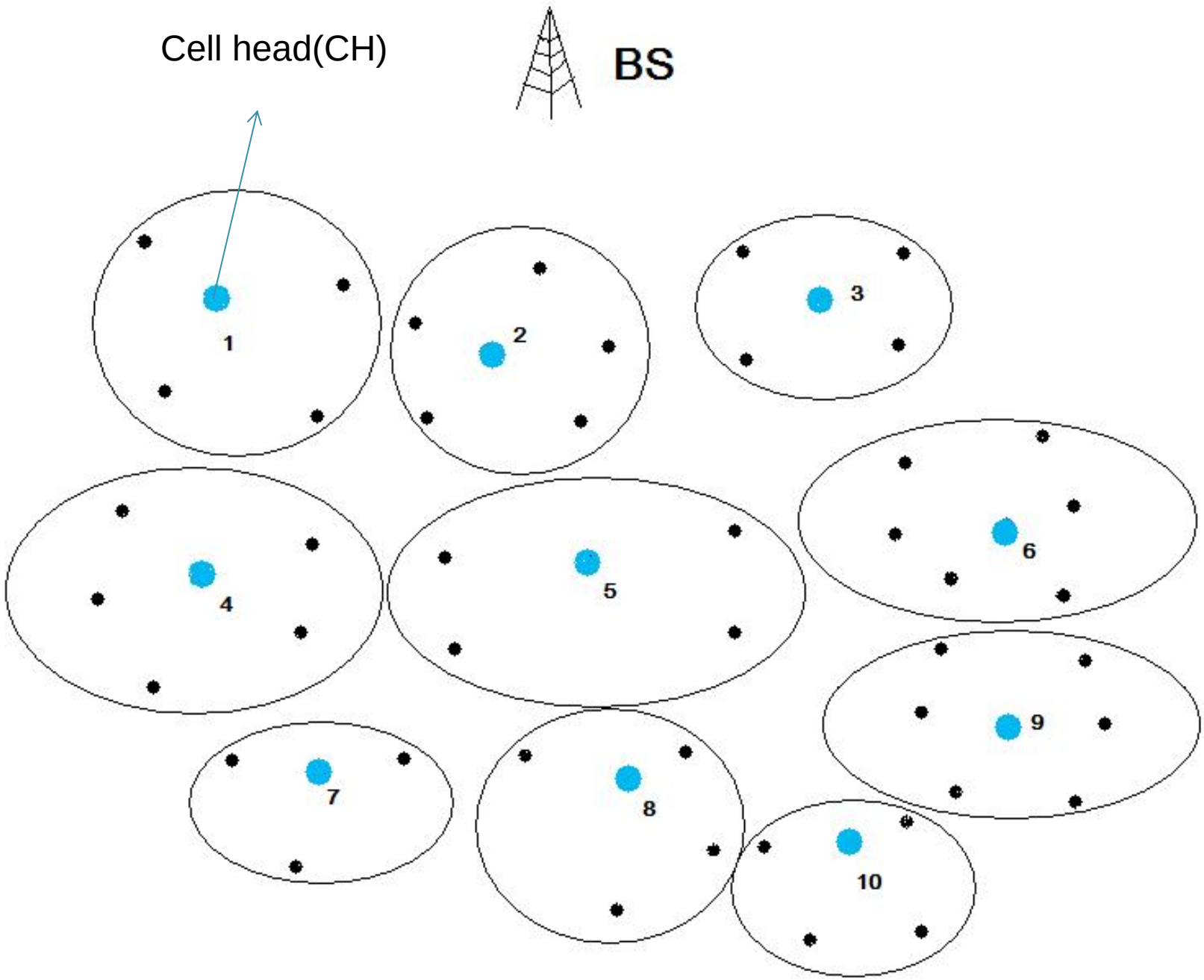
Introduction

- ARCH, a distributed medium access Arbitration of multi-Radio-Channel based sensor networks. ARCH is an energy efficient, scalable and collision free MAC layer protocol that combines frequency and time division principles for medium sharing.

The Architecture and Operational Model

- Sensors group themselves into disjoint cells by applying a distributed randomized clustering algorithm such as HEED [2]


BS
1
2
3
4
5
6
7
8
9
10


Cell head(CH)
BS
1
2
3
4
5
6
7
8
9
10

- Balancing the routing tree will leverage ARCH
- The diameter-constrained routing tree is further constrained to make it balanced. The One-Time Tree Construction algorithm proposed in [3] can be used for that purpose.
- Combining with the tiered network structure make ARCH scalable for large network sizes.

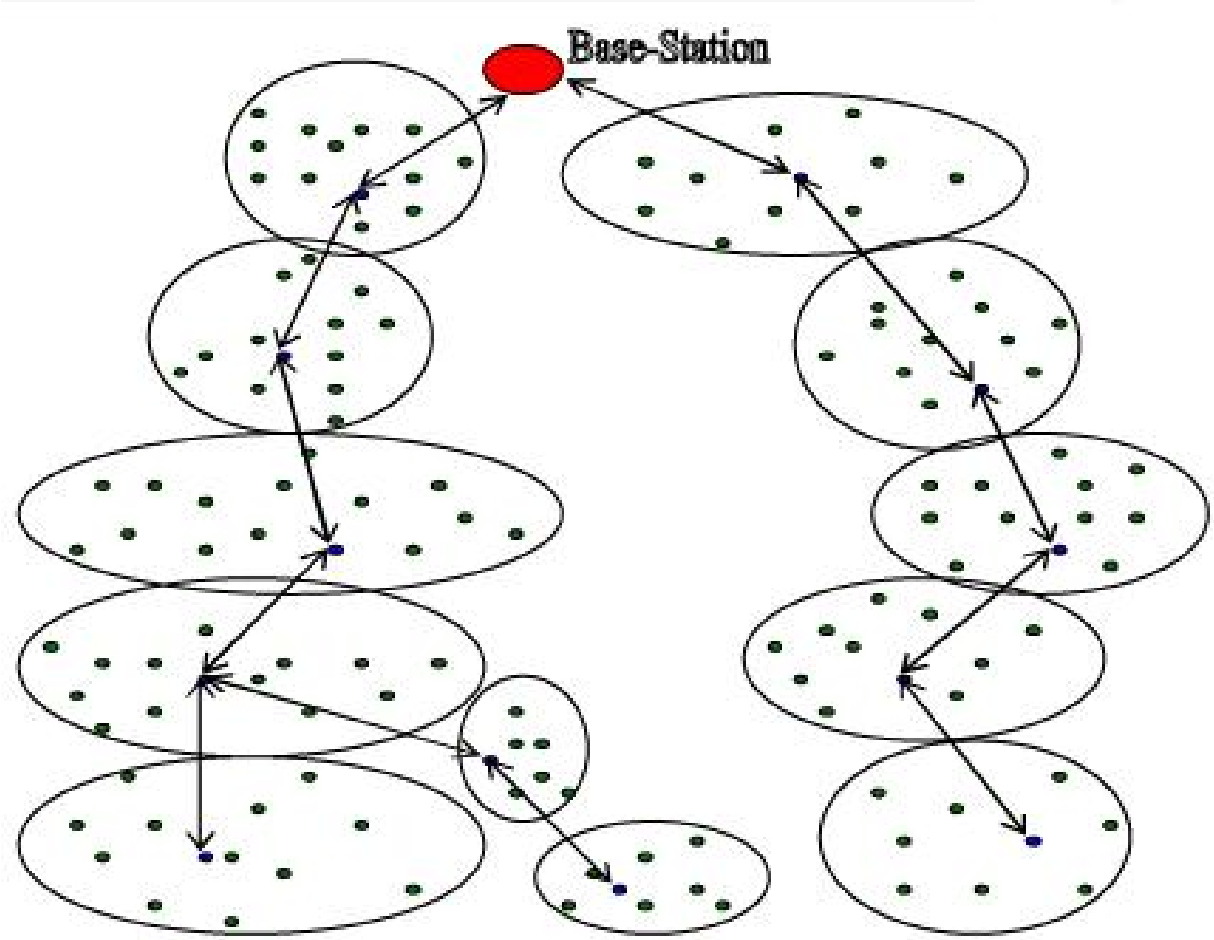
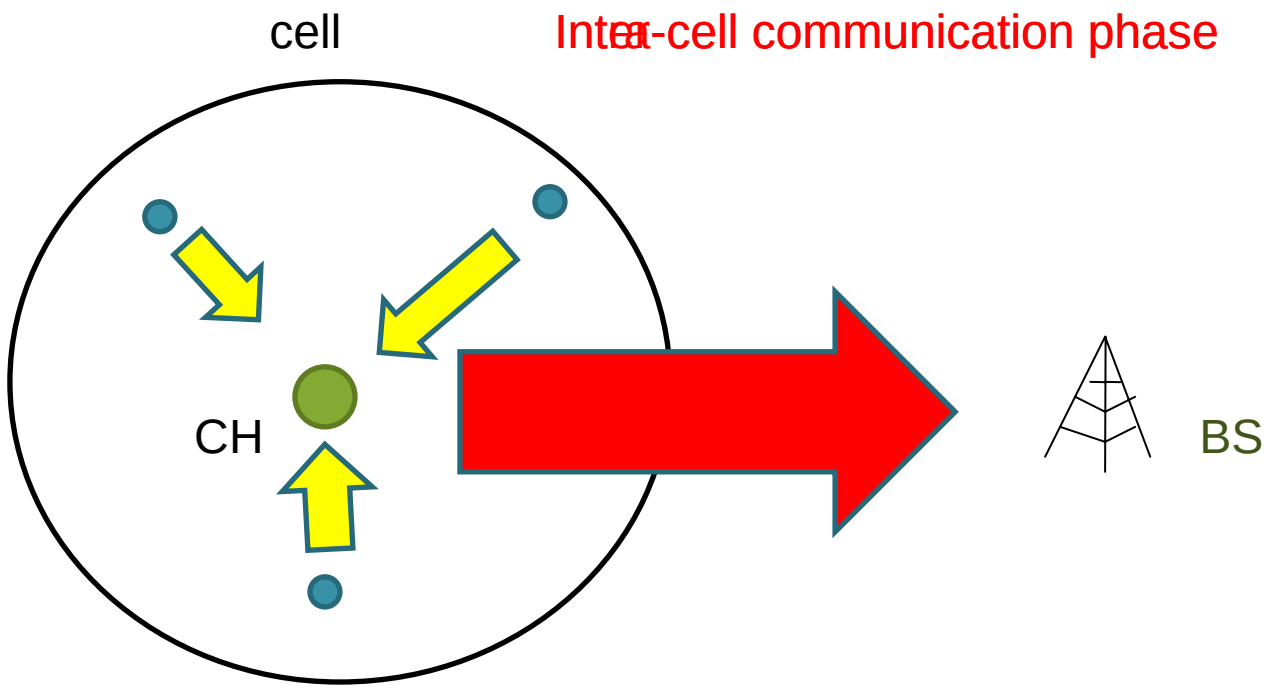


Figure 1: Inter-cell-head routing tree is formed to collect data to the base-station.

Distributed Medium Access Arbitration

- Intra-cell communication phase
  - ARCH's Distributed channel assign algorithm
- Inter-cell communication phase



Intra-cell communication phase

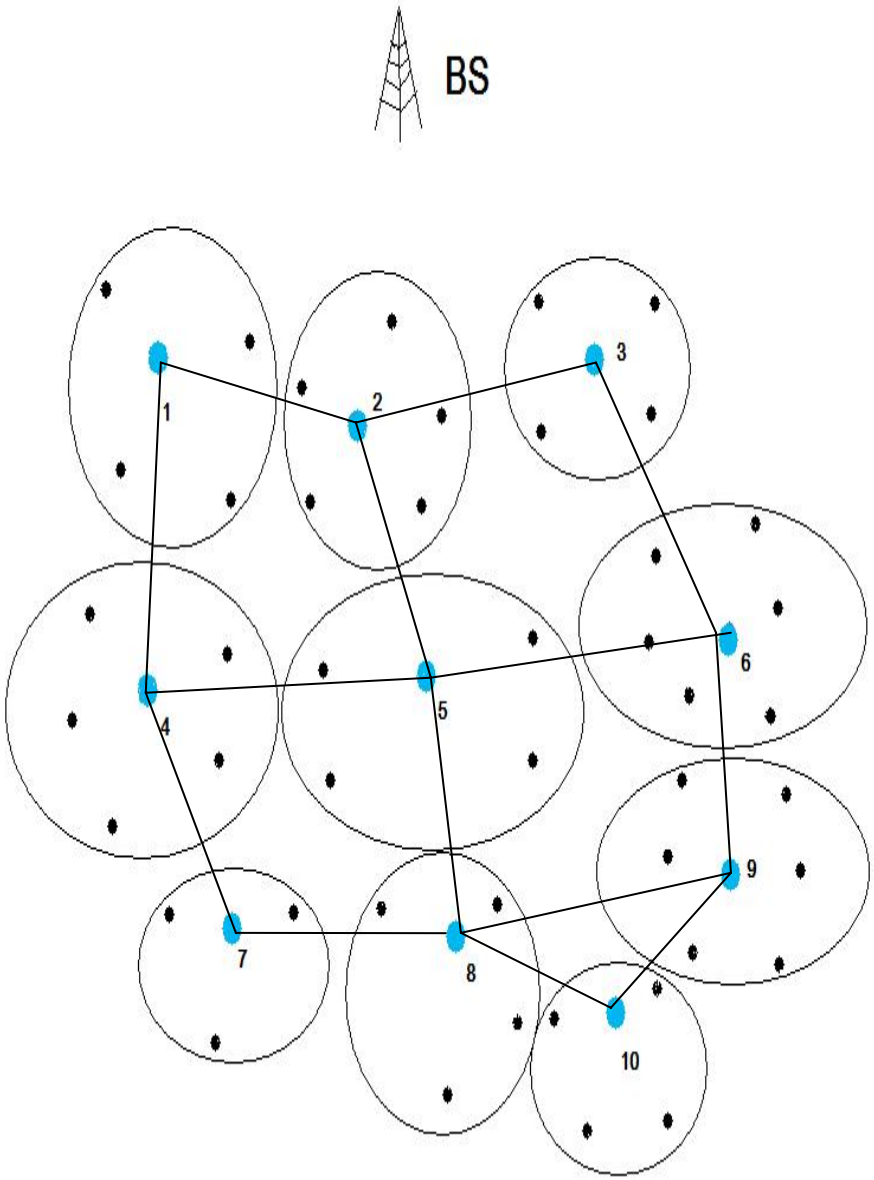
- CHs collect data reports from sensors in their clusters and aggregate them before sending to the BS.
- To prevent intra-cell collisions, we pursue a time-based arbitration of medium access.
- Using distributed channel assignment algorithm assign channel to each cell

distributed channel assignment algorithm

- ***CHi pick s a channel Φi and form set Neighbors(CHi)***
- **Sort *Neighbors(CHi) according to node ID***
- ***j= 1, // point to the top of Neighbors(CHi)***
- **While *IDi < IDNeighbors(j) and j <= | Neighbors(CHi)|***

  do
- **Wait until receiving *ΦNeighbors(j)***
- ***if ($\Phi i \neq \Phi$Neighbors(k) $\forall$ k $\leq$ j) then***
- ***Broadcast (IDi, Φi)***
- ***else***
- ***Select an unused channel Φ***
- ***Broadcast (IDi, Φi)***

Intra-cell communication phase



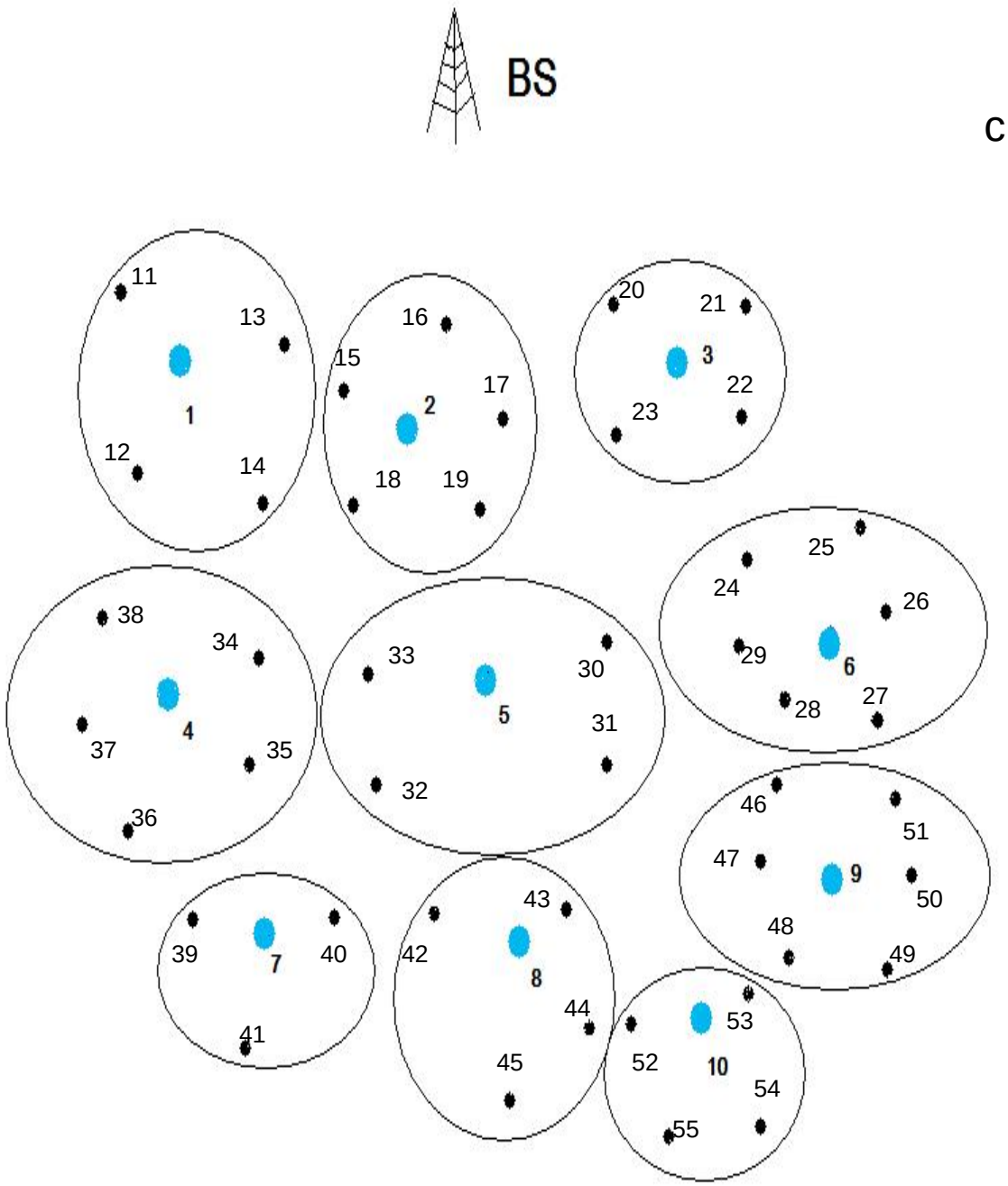
Initial :

Node ID	1	2	3	4	5	6	7	8	9	10
Channel	2	3	2	2	1	4	4	1	3	5

After algorithm :

Node ID	1	2	3	4	5	6	7	8	9	10
Channel	4	5	2	2	3	4	4	1	3	5

Intra-cell communication phase



channel

1	42	43	44	45		
2	20	21	22	23		
	34	35	36	37	38	
3	30	31	32	33		
	46	47	48	49	50	51
4	11	12	13	14		
	24	25	26	27	28	29
	39	40	41			
5	15	16	17	18	19	
	52	53	54	55		

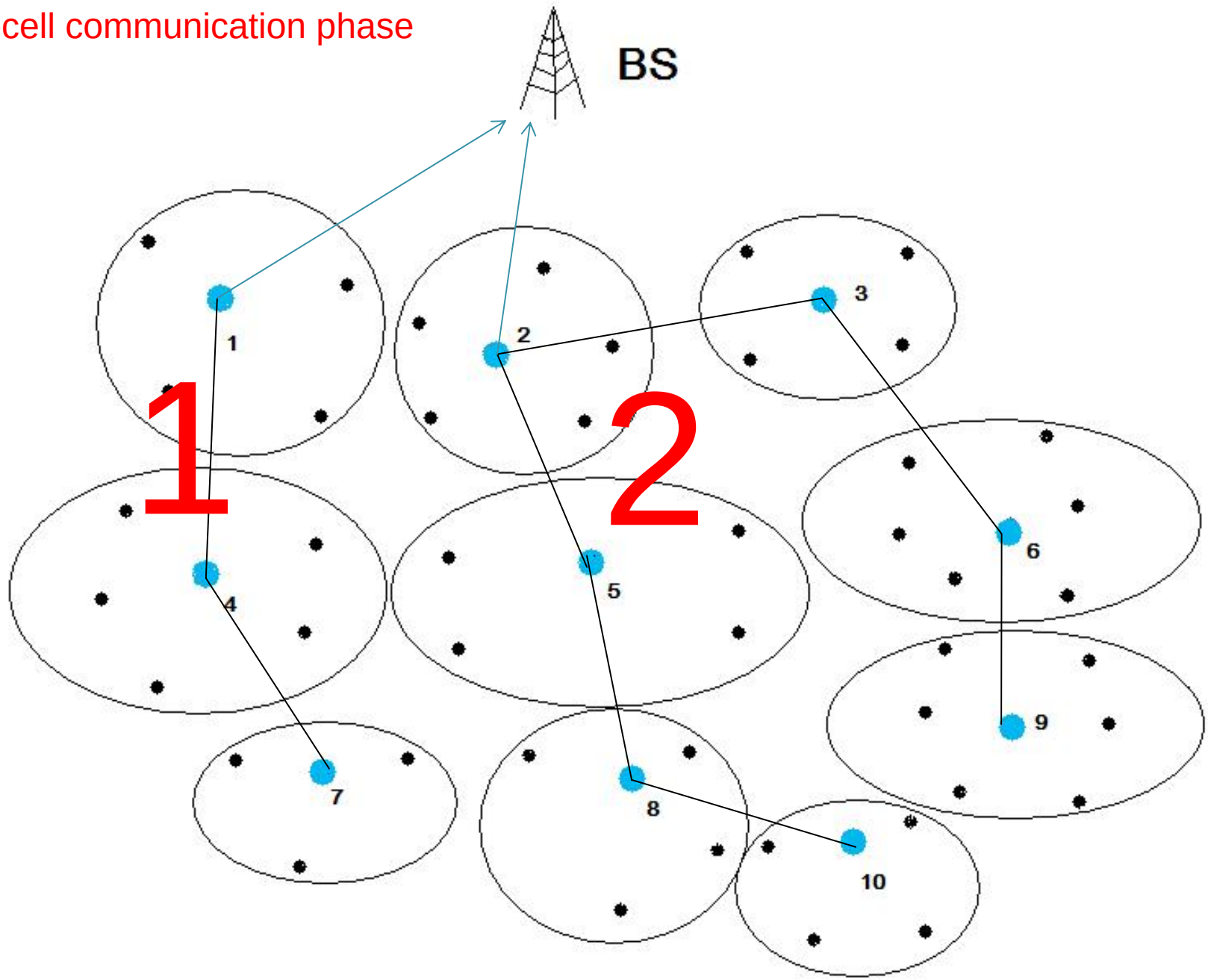
Intra-cell communication phase

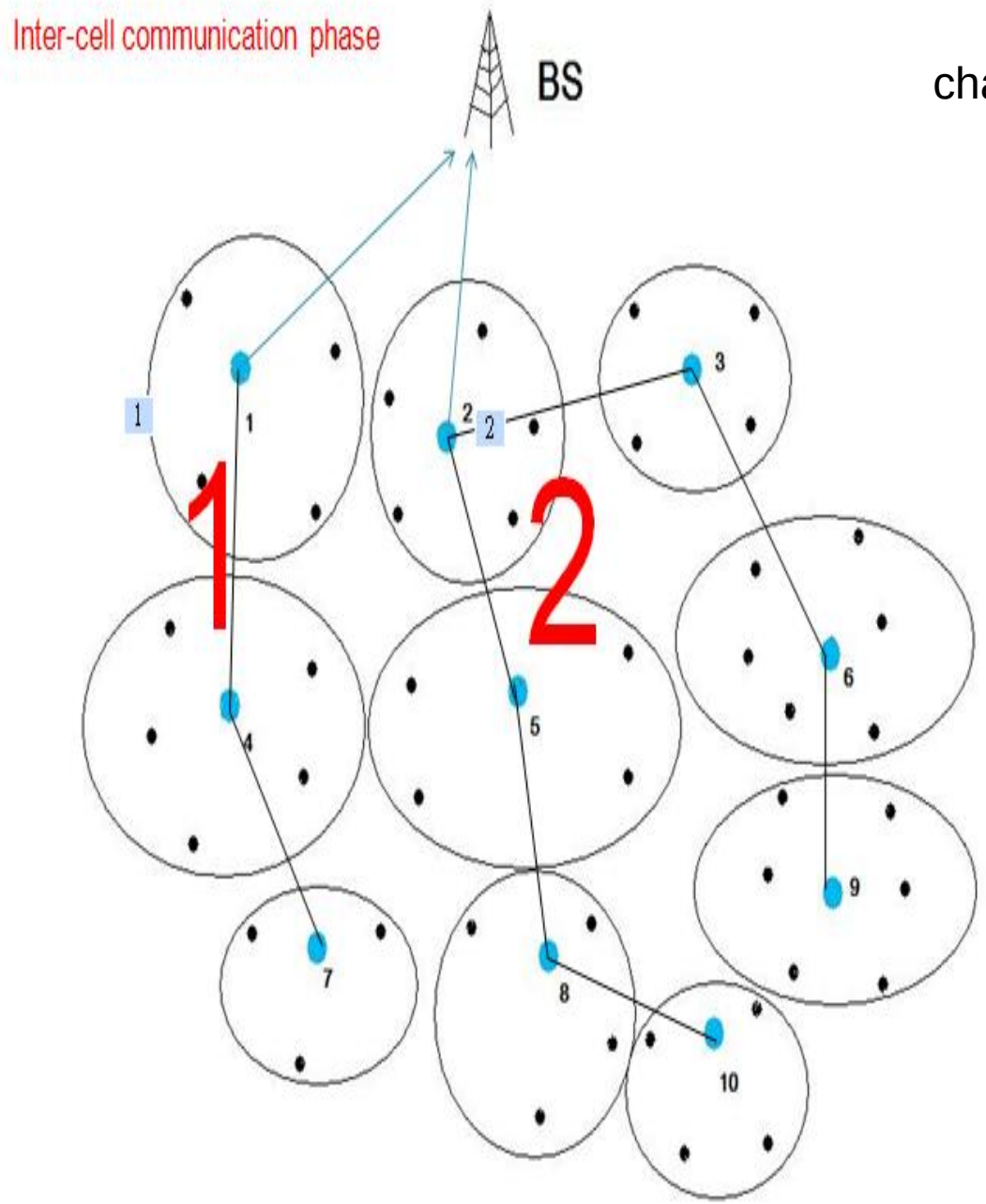
- Since simultaneous transmissions can happen in neighboring cells without collisions, there is no need for a large frame size to accommodate all the cells in the network.
- Frame size smaller => responsive

Inter-cell communication phase

- Use [3] to make a balanced routing tree.
- CH forwards the data report to the BS over an inter-CH path
- To expedite the data forwarding from CHs, a distinct channel is used on the individual independent branches

Inter-cell communication phase





channel

1	7	4	1				
2	10	9	8	5	6	3	2

1	7	4	1	
2	10	8	5	2
3	9	6	3	

Experimental Validation

- *Experiment Setup*
  - using Microsoft Visual C++
  - randomly placed in a 400m x 400m area.
  - The range of a sensor is assumed to be 50m
  - The range of a CH is set to about 1.5 times the range of a normal sensor to ensure connectivity with other CHs.
  - CHs is 5% of sensors

Experimental Validation

- Performance Metrics
  - Average number of neighboring cells with same channel
  - Channel Allocation algorithm convergence rate
  - TDMA frame size

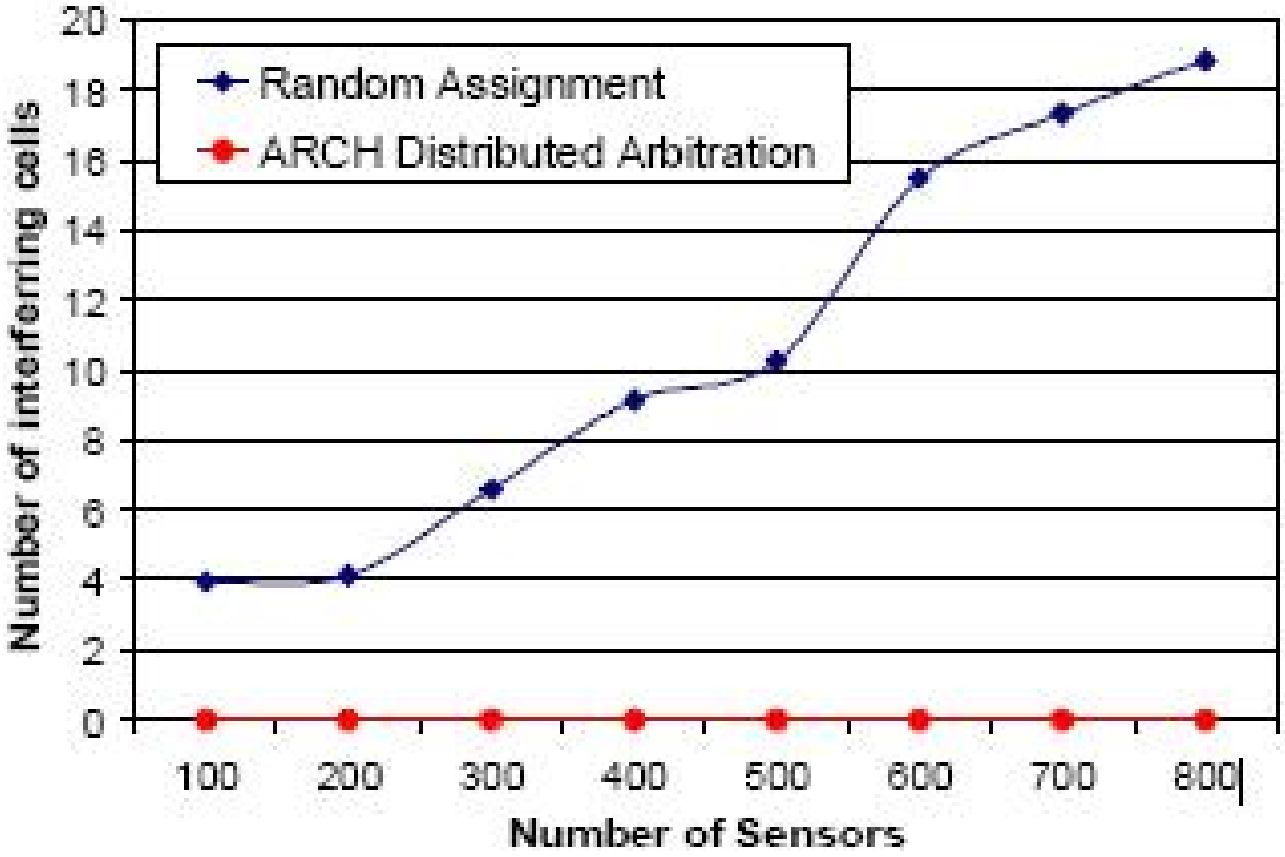
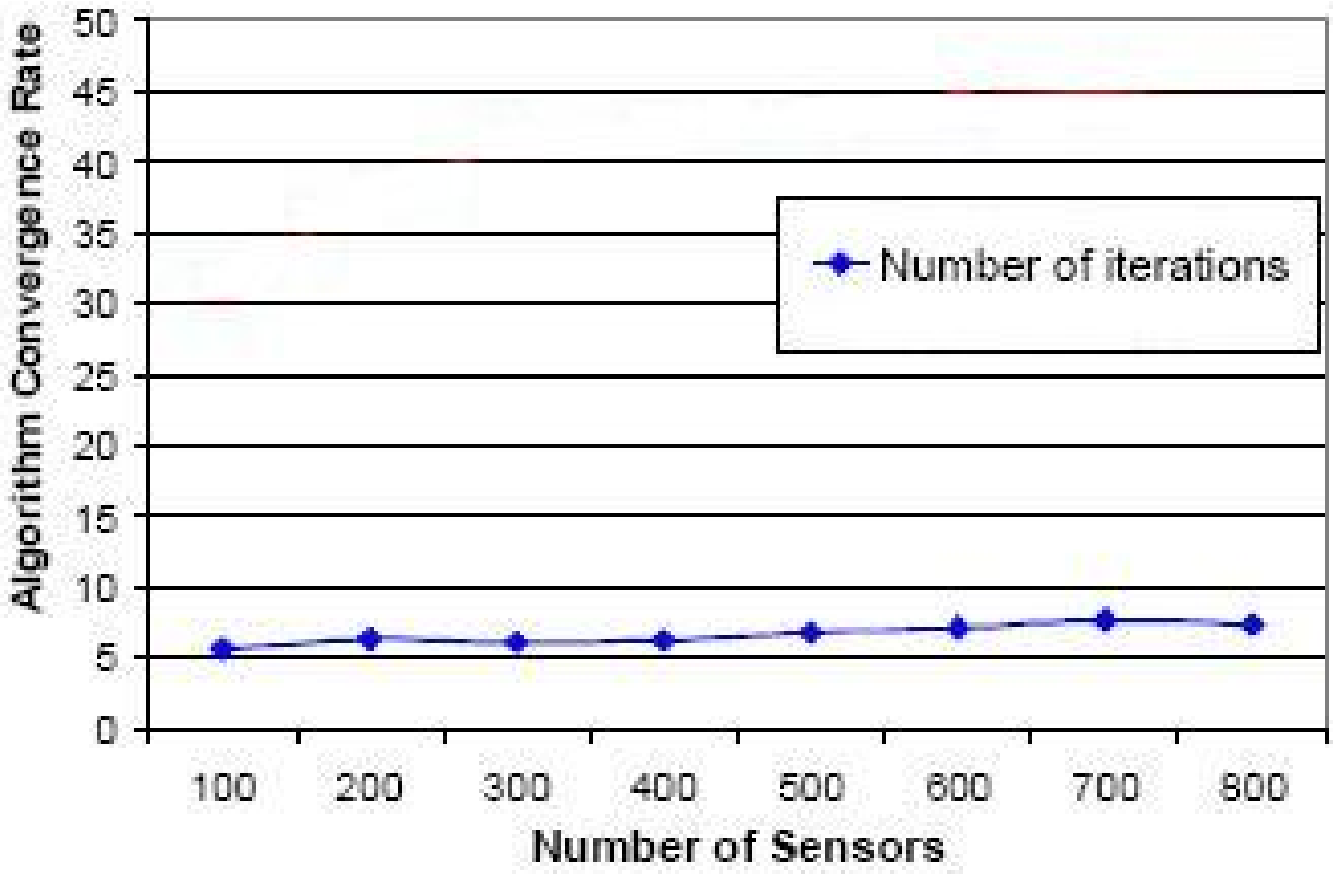


Figure 4: Average number of neighboring cells that use same channel



No of iterations for the ARCH's channel arbitration algorithm to converge

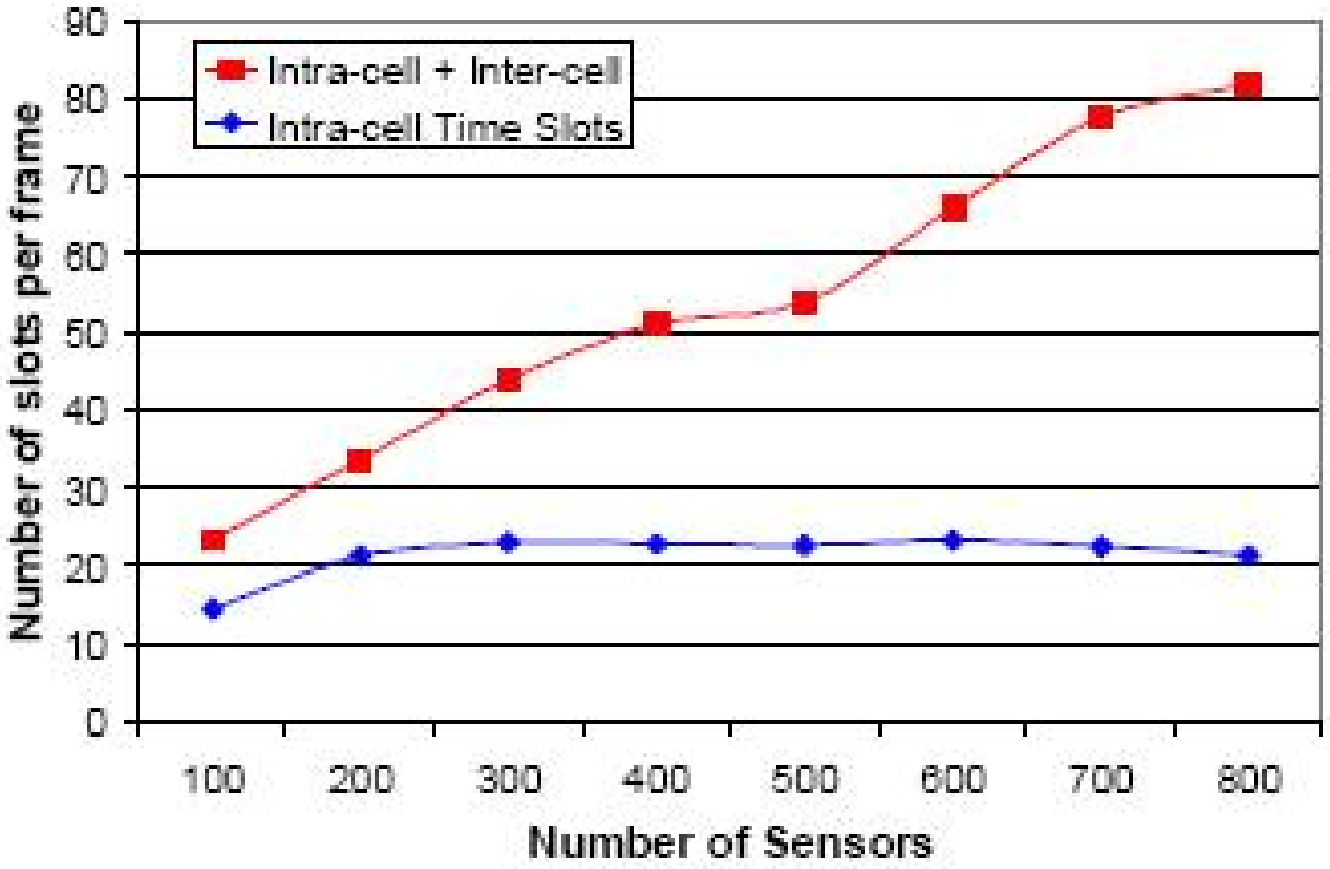


Figure 6: Intra-cell and Inter-cell communication phase frame sizes

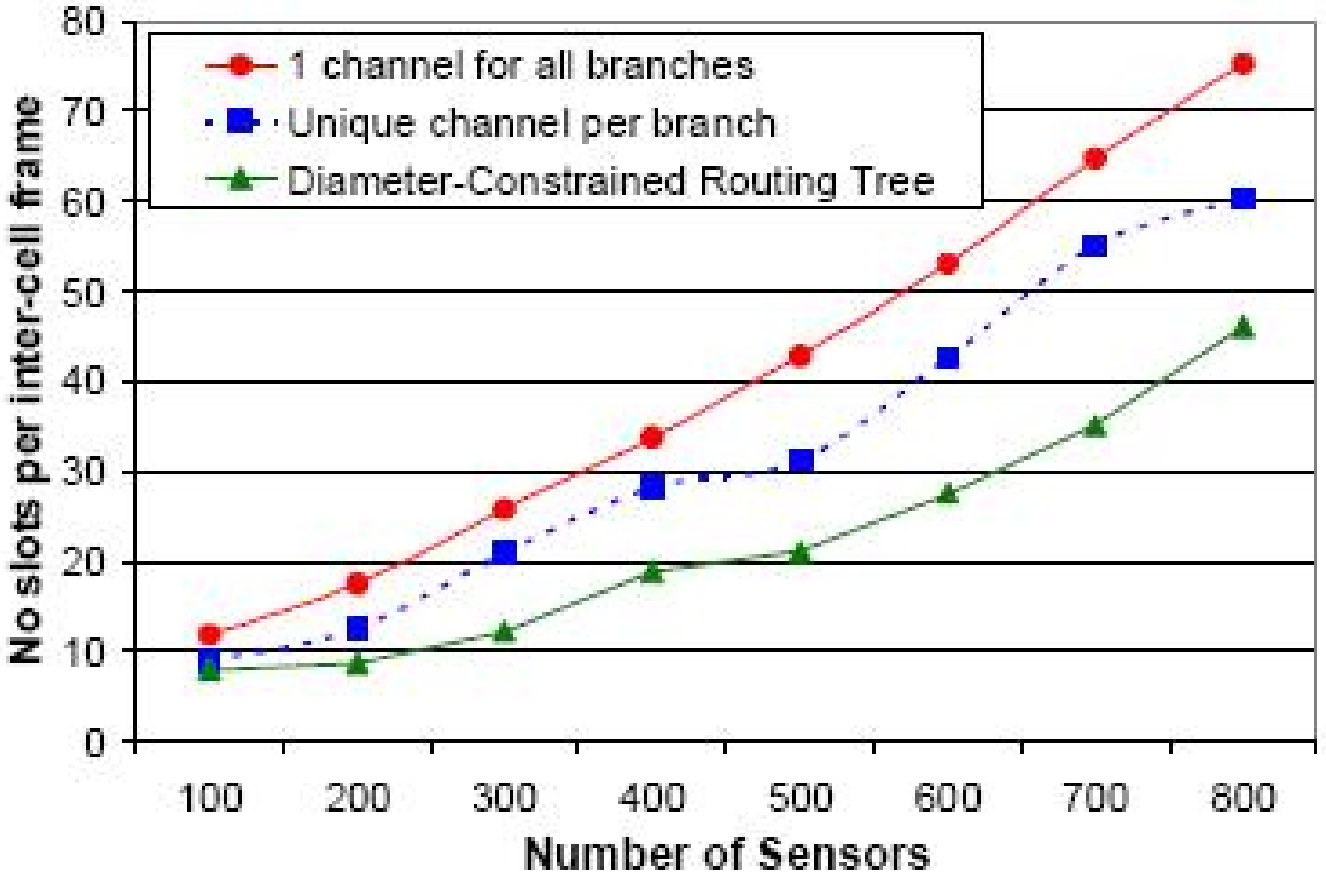


Figure 7: Inter-cell frame size with and without ARCH

Conclusion

- ARCH pursues a combined FDMA and TDMA scheme in order to limit data collection latency and avoid interference among nodes' transmissions.
- efficient, scalable , responsive and collision free