M.Tech Project Defense

MH-WiFiRe : Multi Hop Extension to WiFiRe

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Outline

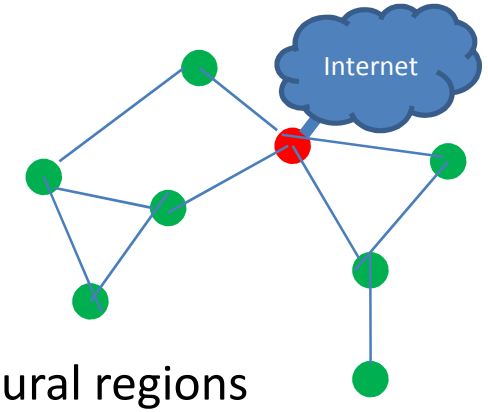
- Introduction
- WiFiRe overview
- Problem Definition
- MH-WiFiRe architectures
- Cost analysis
- MH-WiFiRe
- Performance analysis of MH-WiFiRe
- Contributions & Conclusions
- Future Work

Telecommunication Scenario of India

- In India, "*Communication Revolution*" limited to Urban areas
- Wired connectivity limited to town places
- How to extend connectivity to rural areas ???
- Wired connectivity ??? Not cost effective for rural regions
- Wireless options:
  - Cellular Networks
  - 802.16 WiMax
  - WiFi (802.11)

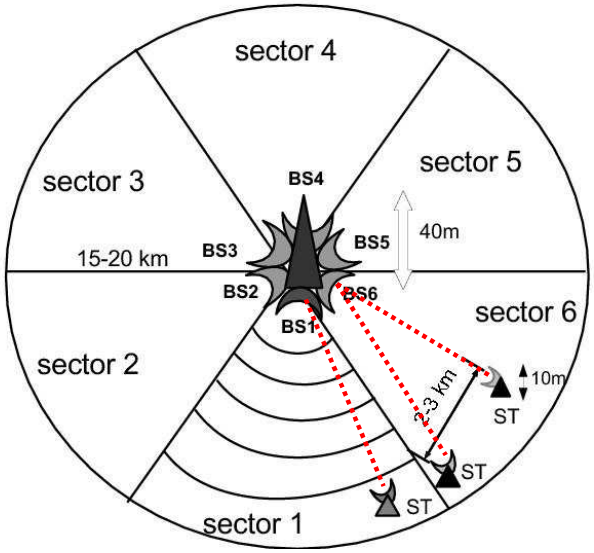
✓ "Last Hop" should be wireless
✓ WiFi is most cost efficient among other wireless technologies

WiFi based long distance wireless networks



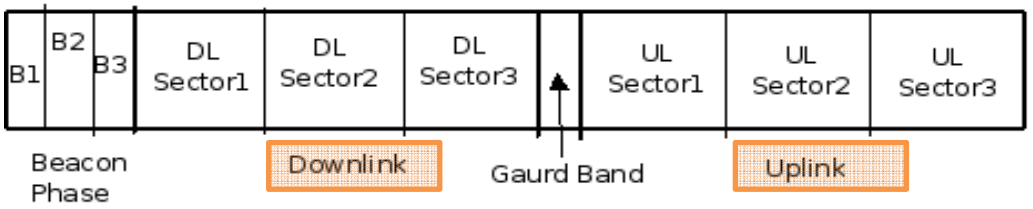
- ❑ Mesh Architecture :
  - Ruralnet: Digital Gangetic Plains (DGP)
  - WiLDNet: WiFi-based Long Distance networks
  - Community Networks in Netherlands
  - Villagenet: Low cost 802.11 based mesh network for rural regions
  - FRACTEL: wi**F**i-based **R**ural **AC**ess and **TEL**ephony
- ❑ Star Architecture :
  - WiFiRe : WiFi Rural Extension
- ❑ Some Examples of Deployments:
  - Digital Gangetic Plains (DGP)
  - Arvind Eye Hospital
  - Ashwini Networks

WiFiRe Overview



Single hop links

WiFiRe Architecture

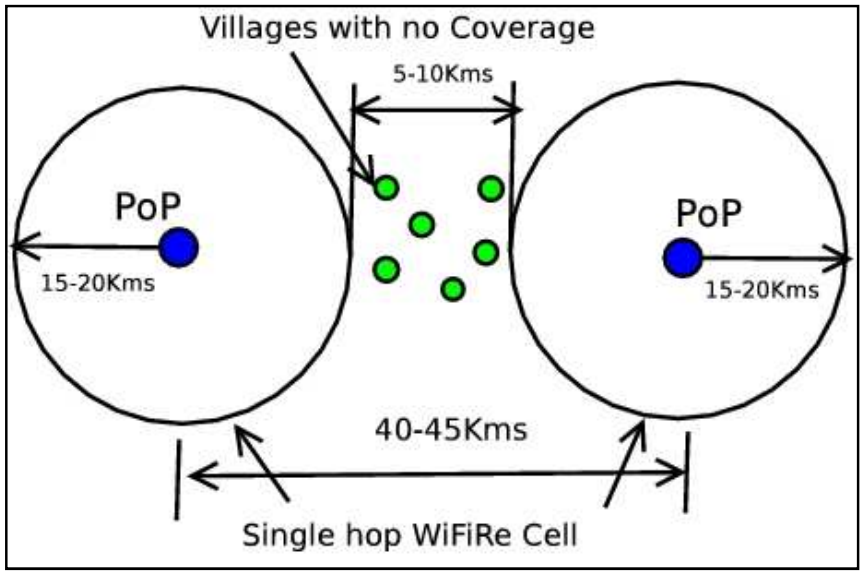


TDMA based WiFiRe Frame

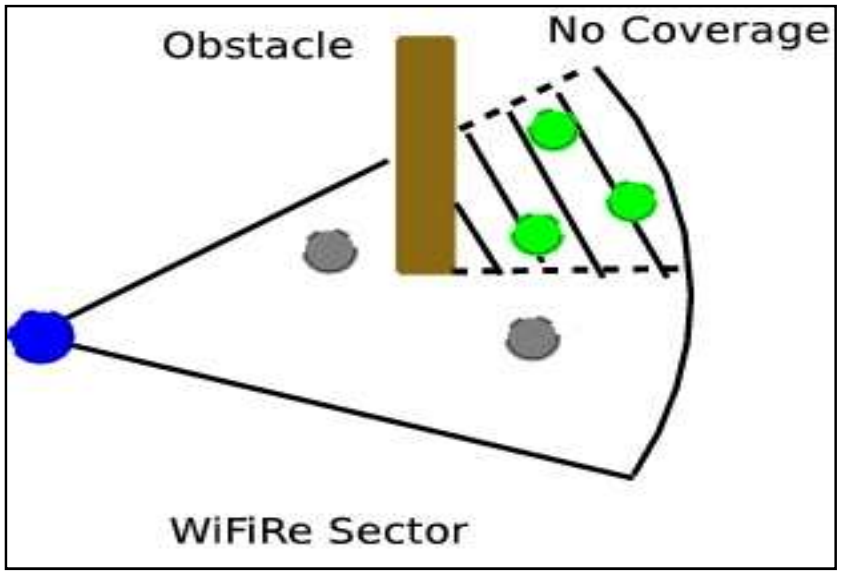
- Villages are separated by 2-3 kms and Town center by 30-40 kms.
- Star topology, Time Division Duplex Multisector (TDM TDD-MSTDM)
- We assume Round Robin scheduling of sectors

WiFiRe Limitations

- Limitations of WiFiRe :
  - Fixed Range
  - Line of Sight (LOS) Requirement
- Limitations due to Singlehop nature, Multihop can overcome limitations



Fixed Range



LOS Requirements

WiFiRe Architecture needs to be extended to ***Multihop*** to overcome its limitations

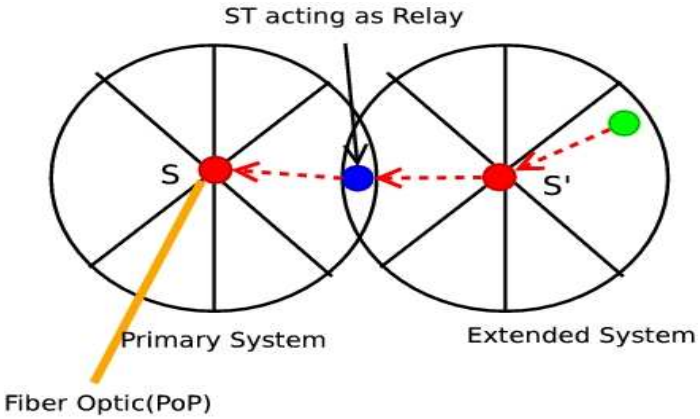
Problem Definition

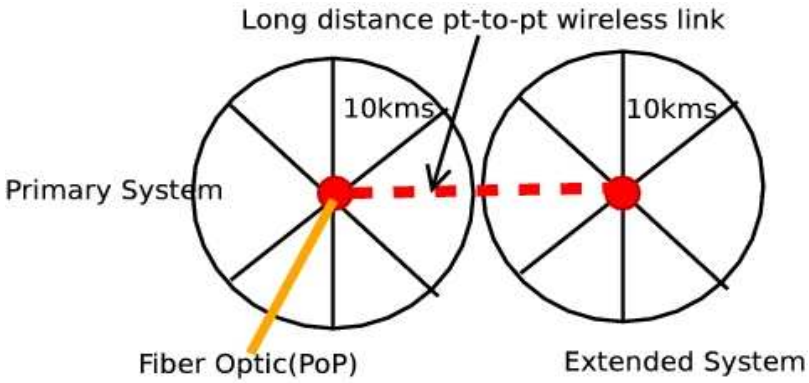
To design a cost-effective multi-hop WiFiRe system which operates over a single wireless channel and alleviates the drawbacks of WiFiRe system

This will involve

- Determining the architecture of multi-hop system
- Cost analysis of the system
- MAC protocol details of the system
- Performance analysis of the system

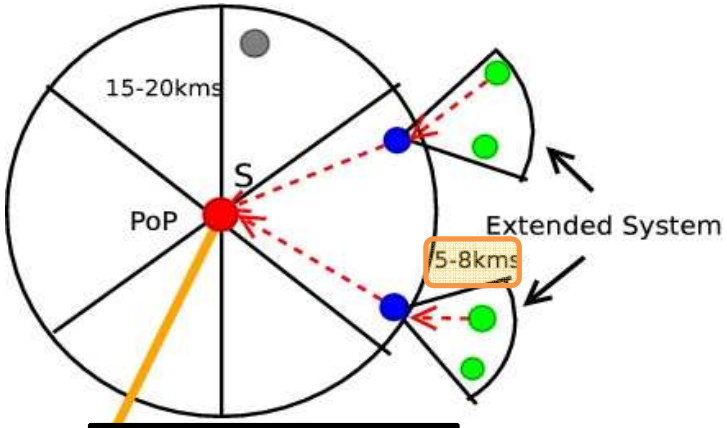
MH-WiFiRe Architectures





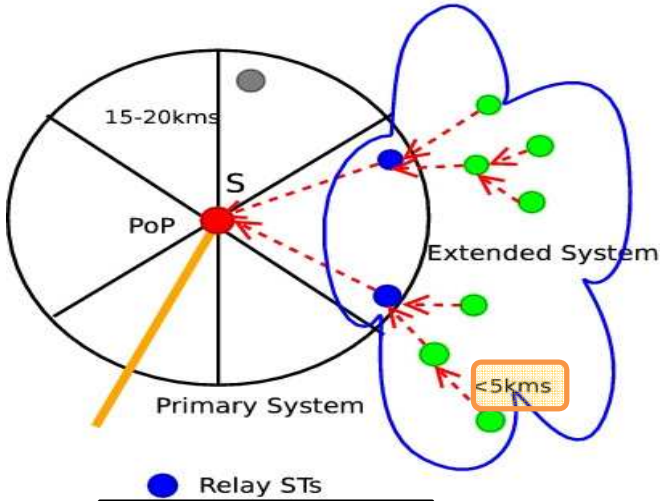
Multi-Hop Wireless Communication

Three Hop Architecture



Sector Architecture

Two Hop Architecture

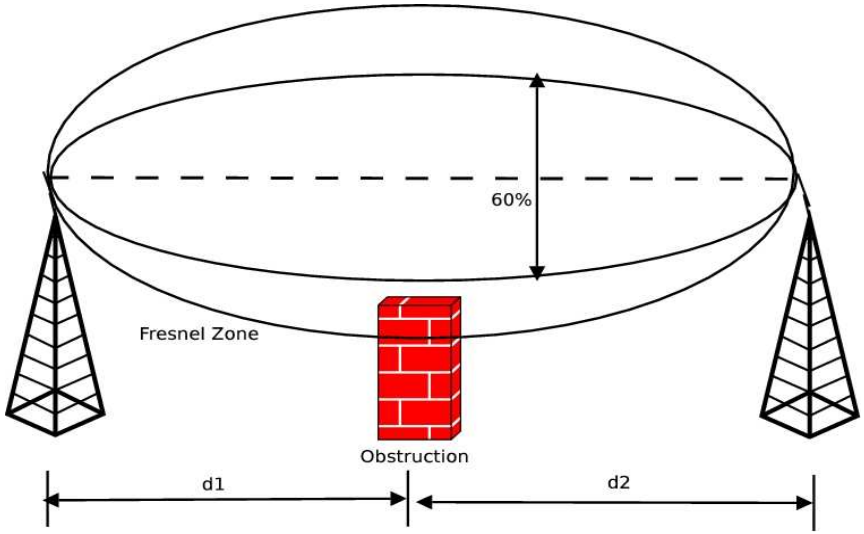


Relay STs

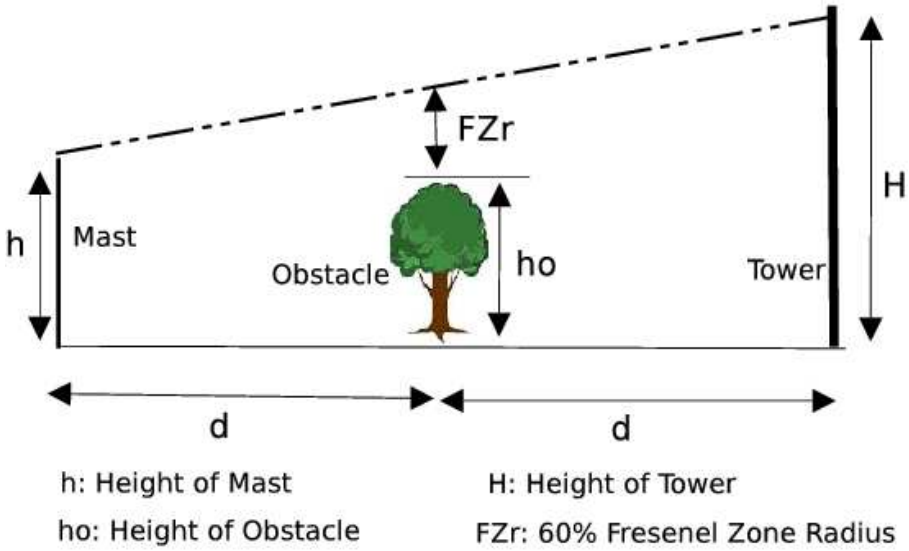
Tree Architecture

Sector & Tree Architectures are more suitable for multihop extension to WiFiRe

Long Distance Wireless Links



Fresnel Zone



Typical arrangement for long distance link

- Requirements: Wireless Link Budget & Wireless Line of Sight (LOS)
- Wireless LOS: 60 % Fresnel Zone clearance; $diam(ft.) = 72.1\sqrt{\frac{d1*d2}{f*(d1+d2)}}$

60% Fresnel Zone Clearance is required to establish a wireless link

Link Distance	Obstacle Type	Link Type
Short Link (<=4 kms)	Small (<=17 mtrs)	Mast-Mast
Short Link (<=4 kms)	Medium (>17&<=30 mtrs)	Tower-Mast
Short Link (<=4 kms)	Large (>30 mtrs)	Difficult to establish link
Long Link (8-10 kms)	Small (<=17 mtrs)	Tower-Mast
Long Link (8-10 kms)	Medium (>17&<=30 mtrs)	Tower-Tower
Long Link (8-10 kms)	Large(>30 mtrs)	Difficult to establish link

Types of Links

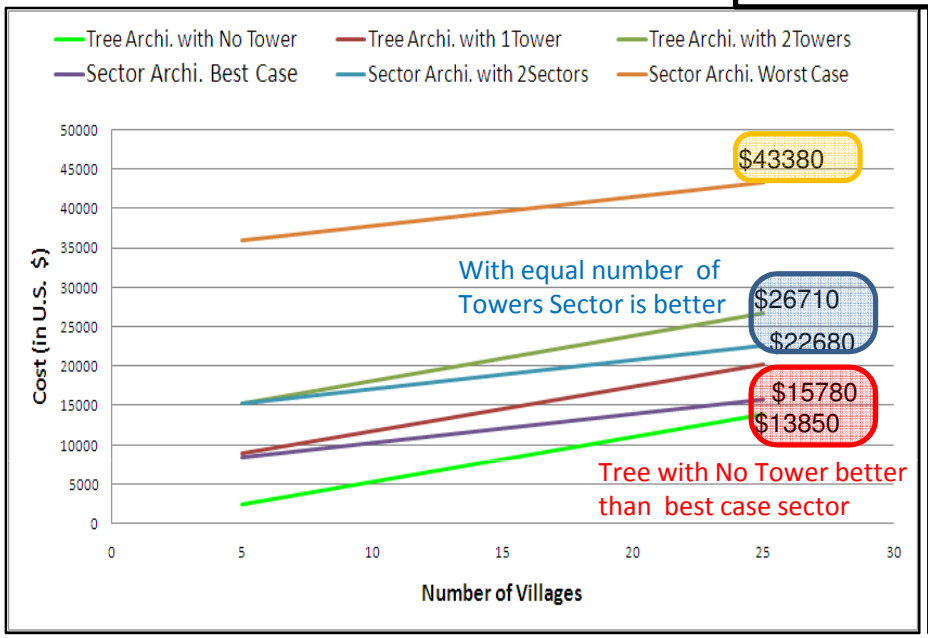
Item	Cost(approx. U.S.$)
Antenna Tower	
15m	$2,300
20m	$3,000
25m	$3,900
30m	$4,800
45m	$6,600
Antenna Mast	
10m	$85
15m	$130
20m	$170

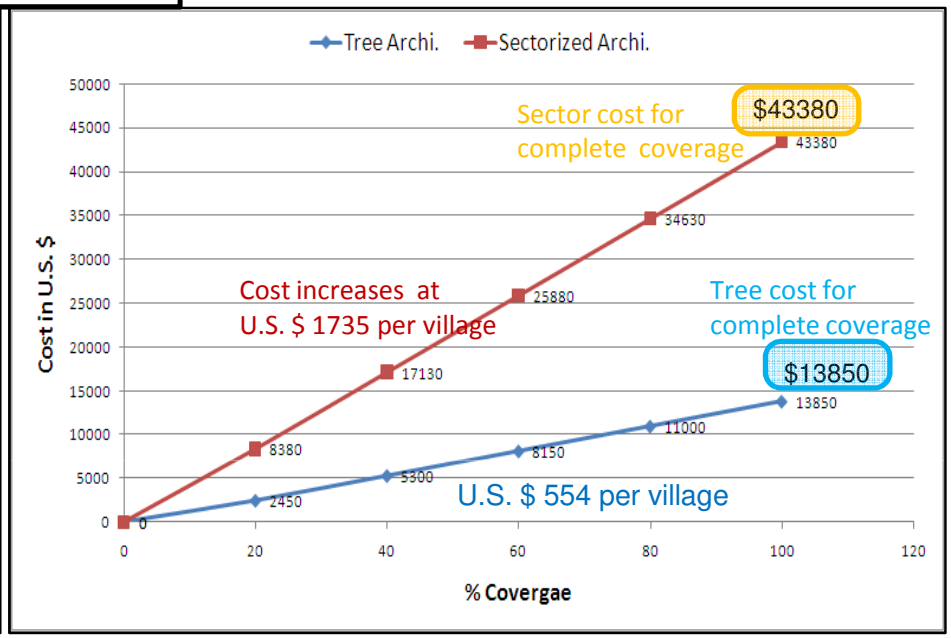
Cost of Mounting structure

- ✓Link type depends on ***Height of obstacle*** & ***Link distance.***
- ✓Sector architecture have ***long links***, which are ***costlier***
- ✓Tree architecture have ***short links***, which are comparatively ***cheaper***

Cost analysis of Tree & Sector Archi.

Cost Vs Coverage





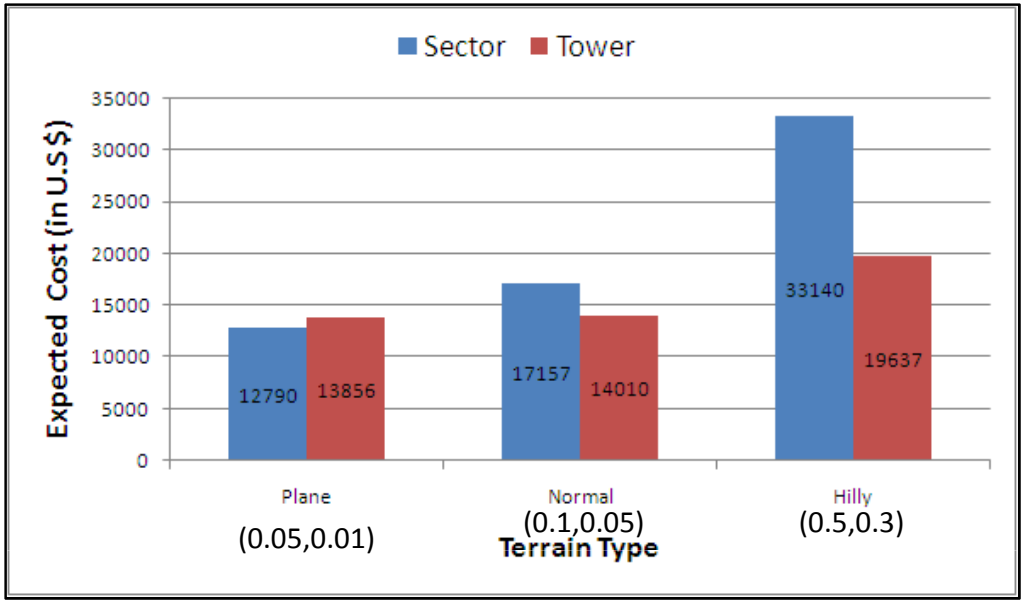
Assuming extended area of 160 km^2 and one village per 6 km^2 we consider 25 villages in for our analysis

- Cost of best case sector architecture is **more** than best case tree architecture.
- For equal number of towers, Sector architecture is cost efficient than Tree architecture.

Assuming uniform distribution of villages and 60° beamwidth of the sector antenna, 5 sectors required to cover entire area.

Tree architecture is more cost efficient than Sector architecture

Probabilistic Cost Model



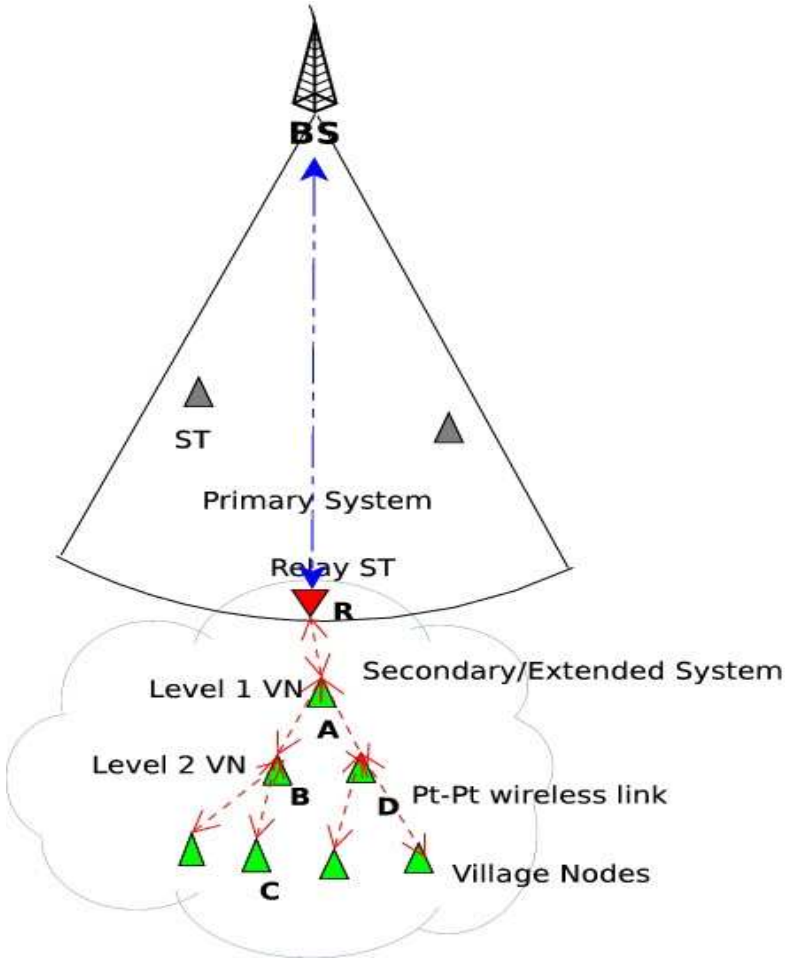
- In probabilistic model, we assign different probabilities for the occurrence of different obstructions and then determine the expected cost of the system.
- *[p;q]* : [P(Small obstacle between a link) *;* P(Medium obstacle between a link)]
- Expected cost of the system = $\sum_{x=1}^{x=N}$ P('x' towers)*Cost('x' towers)
- P('x' towers) and Cost('x' towers) will be different for Tree and Sector architecture

Thus Tree architecture offers following advantages over Sector architecture:

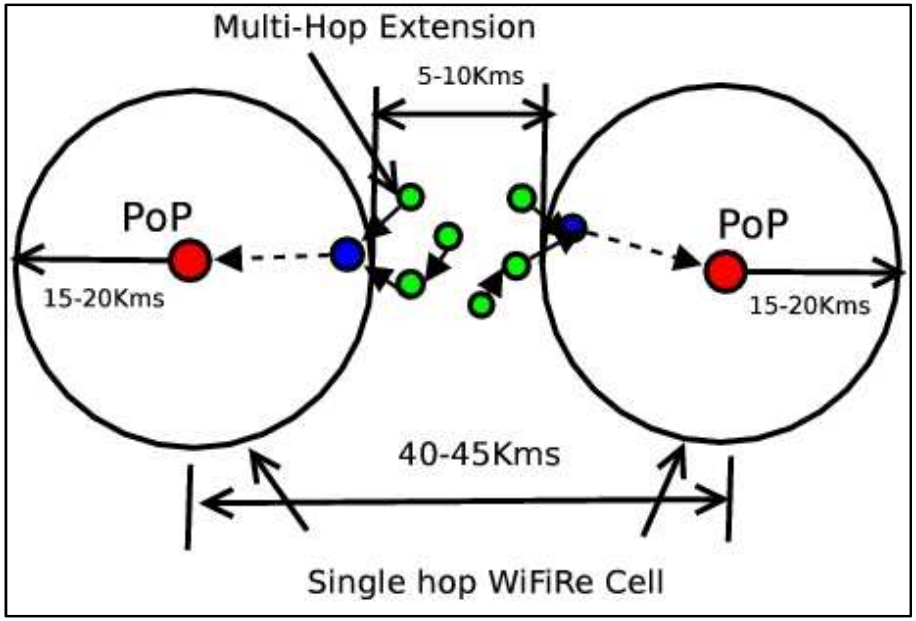
- Cost Effective, Supports more number of Calls (1.3 vs 5 calls/village)& No Voids

MH-WiFiRe Architecture

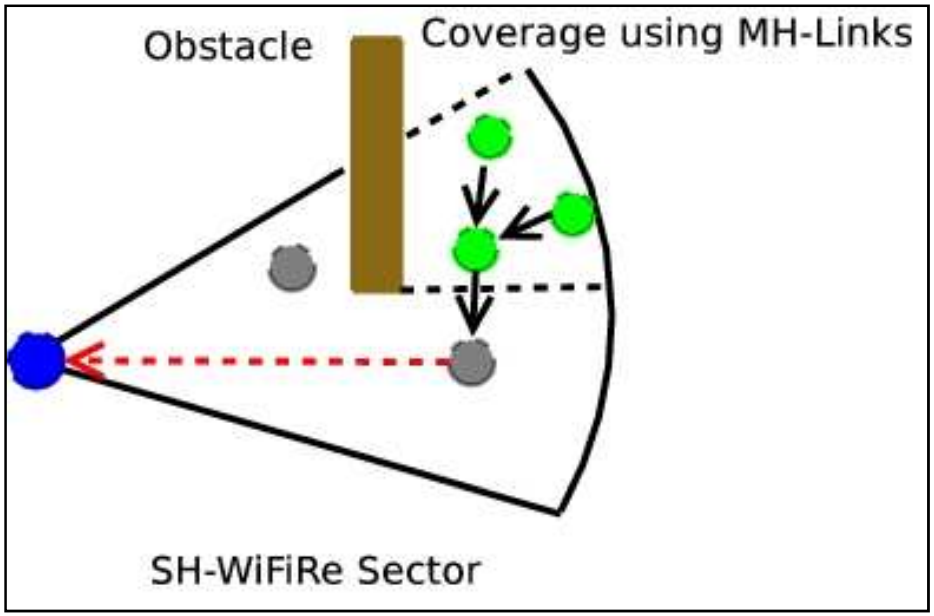
- Various Components:
  - Base Station (BS), Subscriber Terminal (ST), Relay ST, Village Node (VN), Downlink (DL) and Uplink (UL) successor.
- Assumptions:
  - Round Robin (RR) scheduling
  - Synchronized Village nodes
  - Only VoIP Traffic
  - Equal number of UL and DL slots
  - Non-interfering point-to-point links
  - Reliable system.



Advantages over WiFiRe



Fixed Range limitation

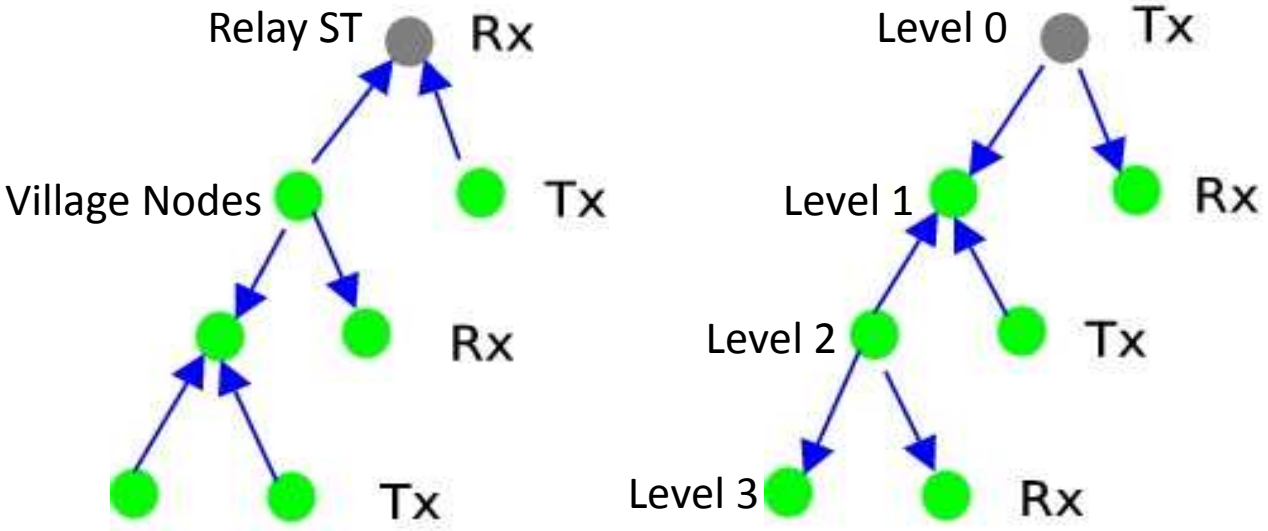


LOS Requirement

MH-WiFiRe overcomes both the limitations of WiFiRE

Scheduling in MH-WiFiRe

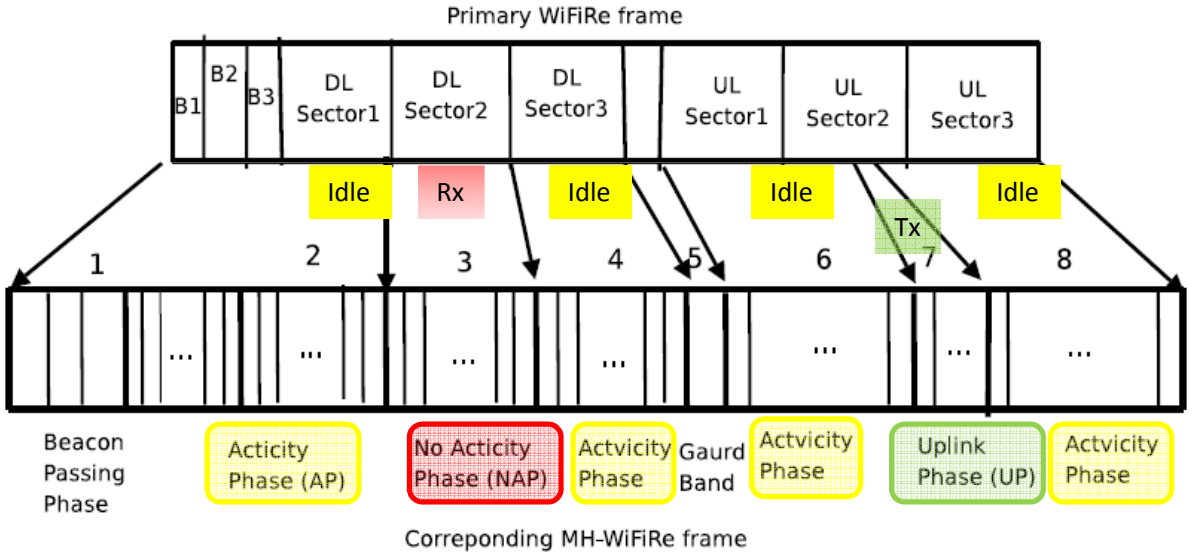
- MH-WiFiRe is also TDMA based similar to WiFiRe.
- Scheduling scheme used is similar to 2P.
- Scheduling algorithm schedules the mode of the relay ST for all the slots of the frame. Modes of other VNs gets automatically decided.



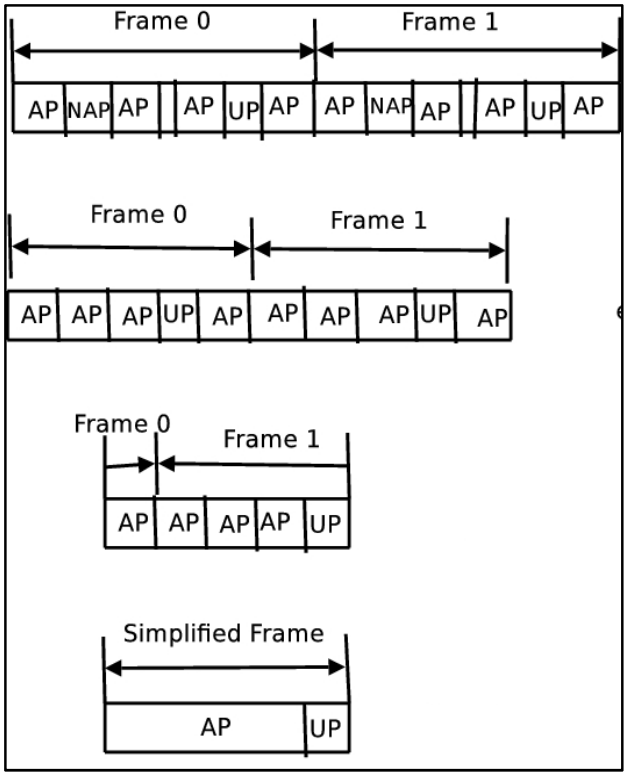
Scheduling algorithm schedules only relay ST's mode

MH-WiFiRe Frame Structure

- ST in Primary WiFiRe can be in one of the three phases:
  - Transmitting, Receiving or Idle
- We simplify frame structure for analysis purpose

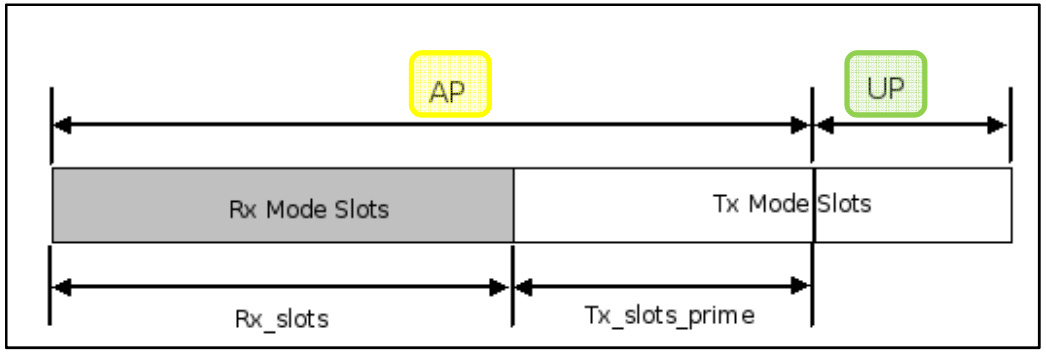


MH-WiFiRe Frame



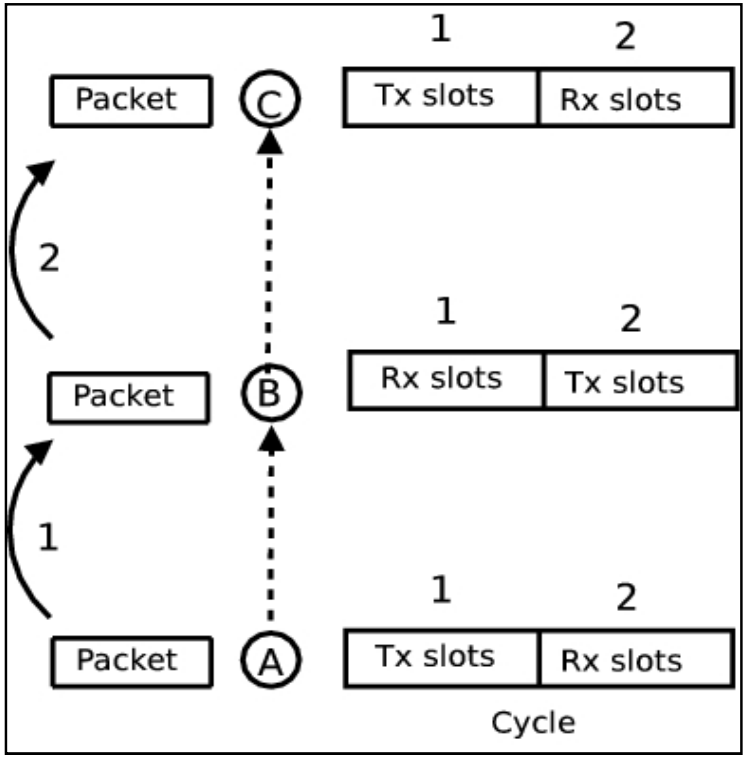
Frame Simplification

Simple Scheduling Scheme



Simple scheduling scheme

- Simple scheduling scheme:
  - Schedule all Rx_slots followed by Tx_slots
- Cycle : A group of consecutive slots, which contains one or more Tx slots followed by one or more Rx slots.



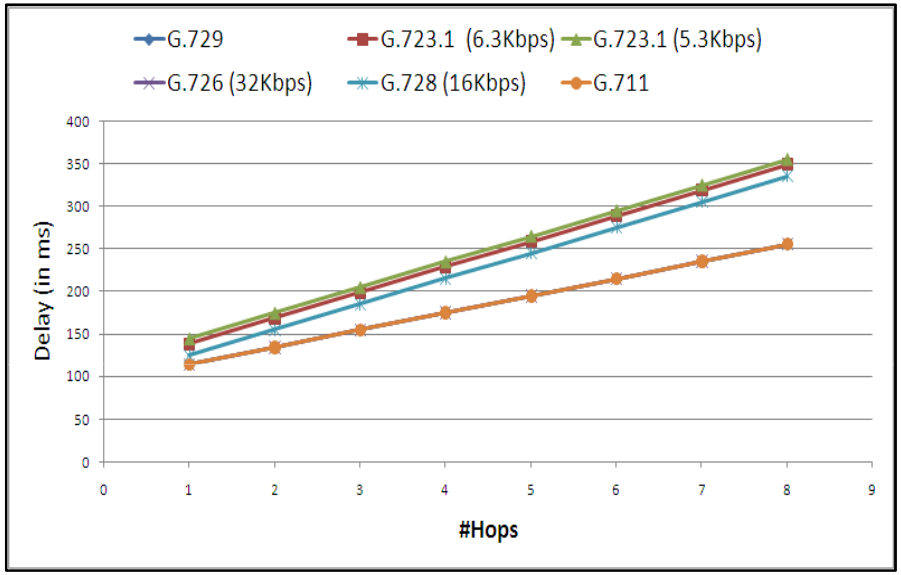
Significance of cycle

✓ End-to-end delay should be less than tolerable VoIP delay
✓ Frame size depends on VoIP periodicity
✓Slot size depends on VoIP packet size

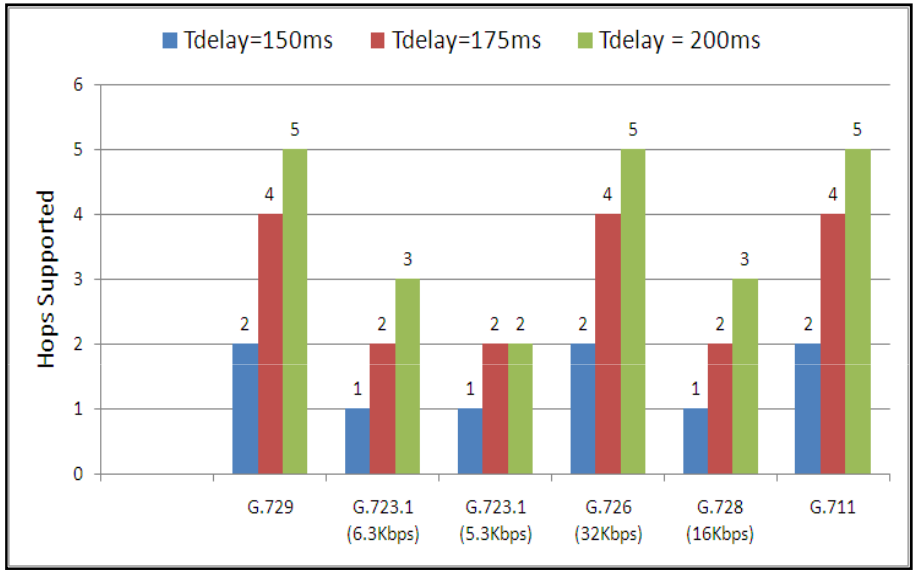
In every cycle, the packet will move ahead at least by one hop

Performance analysis of Simple scheduling scheme

- Delay Analysis:



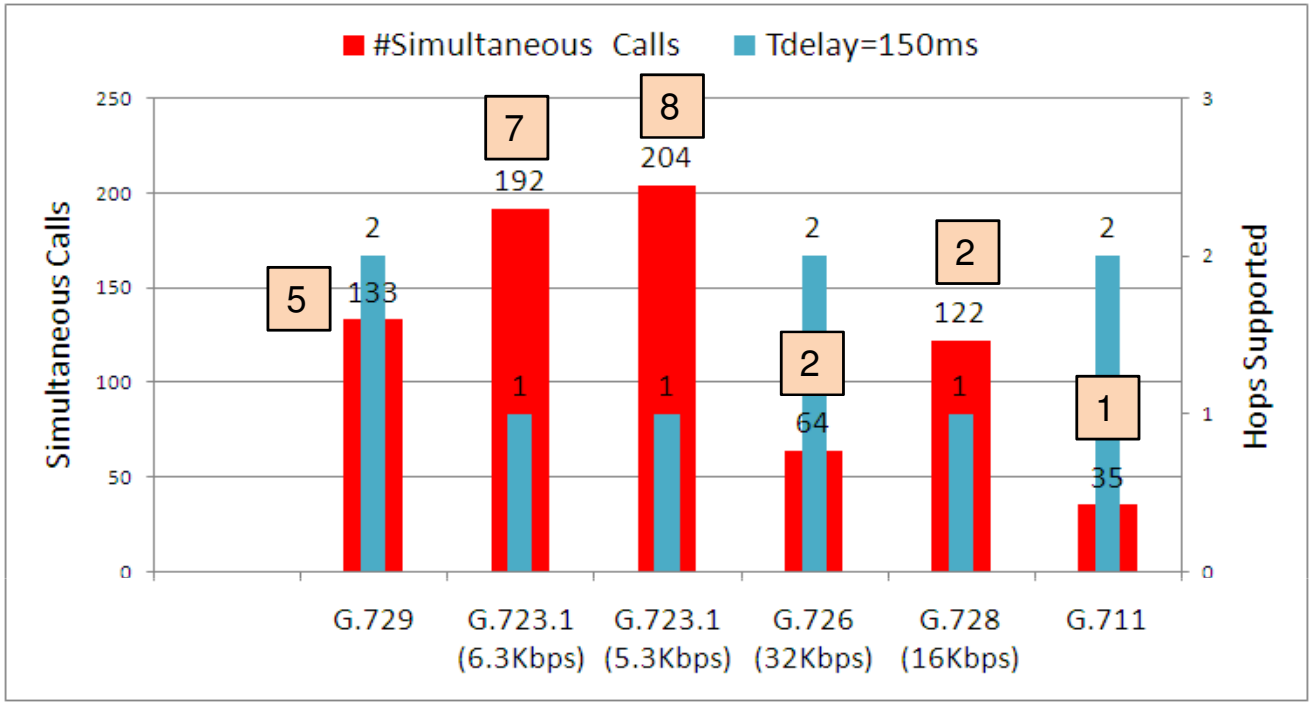
Delay w.r.t. hops



Hops supported for different codecs

- Delay varies linearly with hops.
- Increase in delay at every hop is equal to the frame size.
- For acceptable VoIP quality, end-to-end delay should be less than tolerable VoIP delay.
- Tolerable VoIP delay according to IETF standard is 150 msec.
- Only 1 or 2 hops are supported, beating the purpose of multihop extension

- Number of Calls supported:

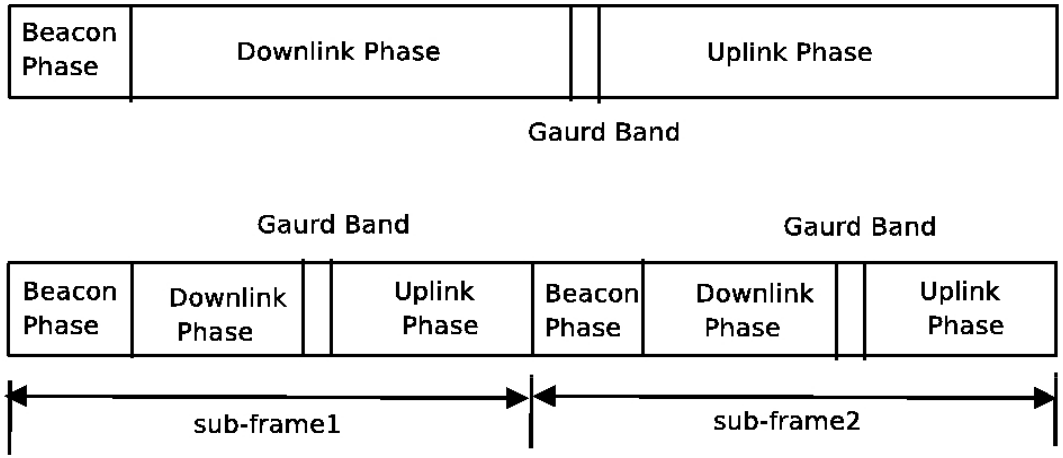


- Assumption: All calls are from Secondary system, no calls from Primary system
- Most of the codecs support more than 5 calls/village but number of hops are less
- Need a scheme that can perform trade-off between Hops and Calls
- Two scheduling scheme presented here are:
  - Sub-frame scheme
  - Cycle scheme

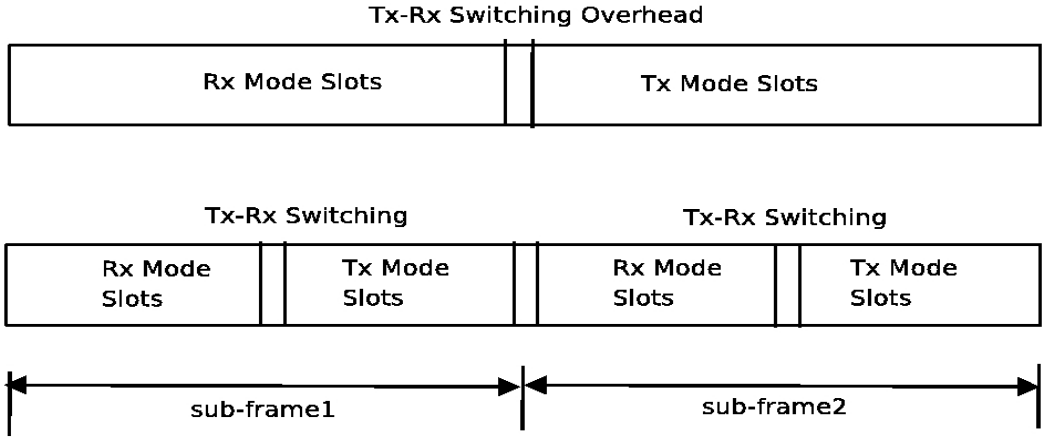
Scheduling scheme should allow to perform trade-off between Max. Hops supported and Simultaneous Calls

Other Scheduling schemes

- Sub- frame scheme:
  - Size of Primary WiFiRe frame is reduced.

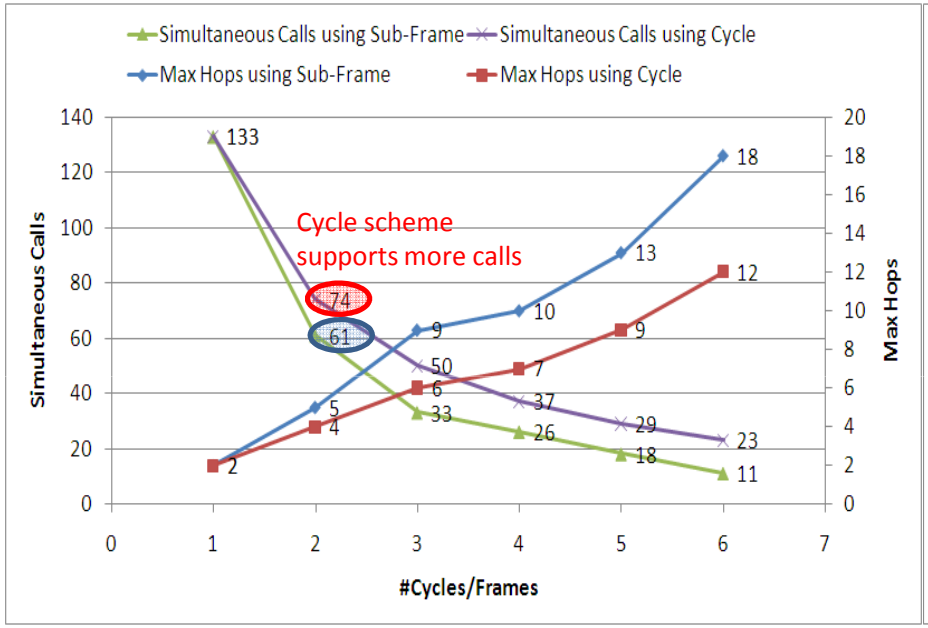


- Cycle scheme
  - The MH-WiFiRe frame is divided into more number of cycles

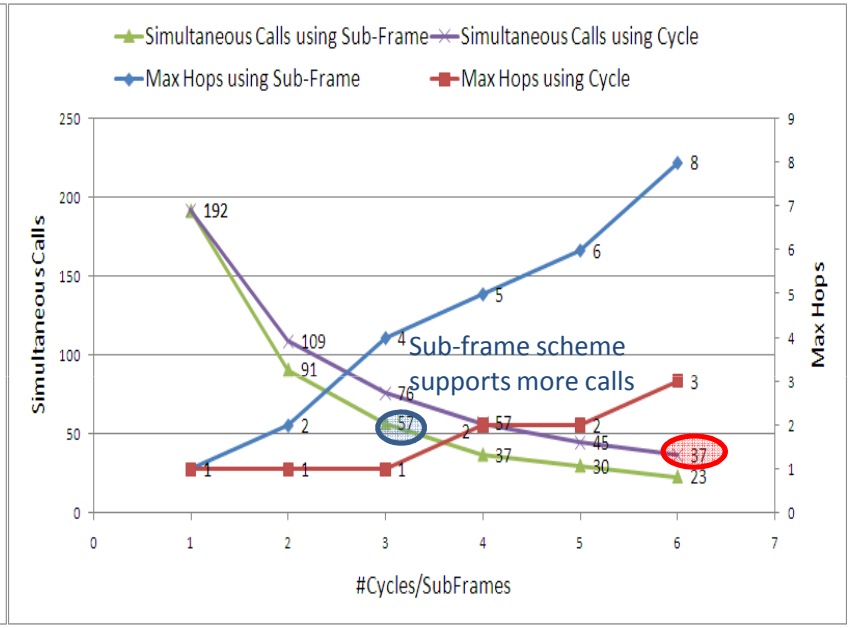


Performance Analysis

- Max. Calls from Secondary system with No calls from Primary system



G.729 Codec



G.723.1(6.3Kbps)

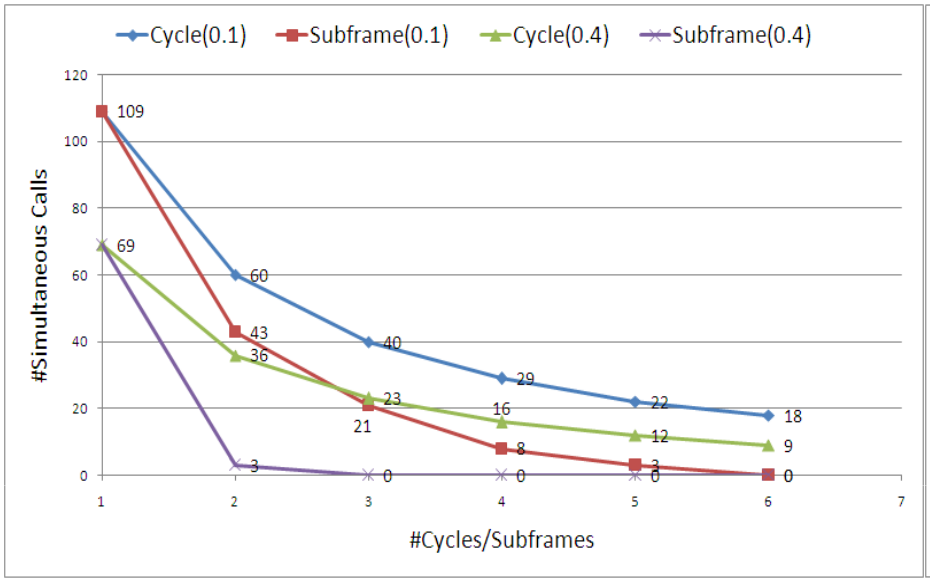
Assuming we need to support Three hops

Codec	Hops Supported		Simultaneous Calls		Number of	
	Sub-frame	Cycle	Sub-frame	Cycle	Sub-frames	Cycles
G.711 (64 Kbps)	5	4	12	15	2	2
G.729 (8 Kbps)	5	4	61	74	2	2
G.723.1 (6.3Kbps)	4	-	57	-	3	-
G.723.1 (5.3Kbps)	4	-	40	-	4	-
G.726 (24 Kbps)	5	4	27	32	2	2
G.728 (16 Kbps)	5	4	34	34	3	4

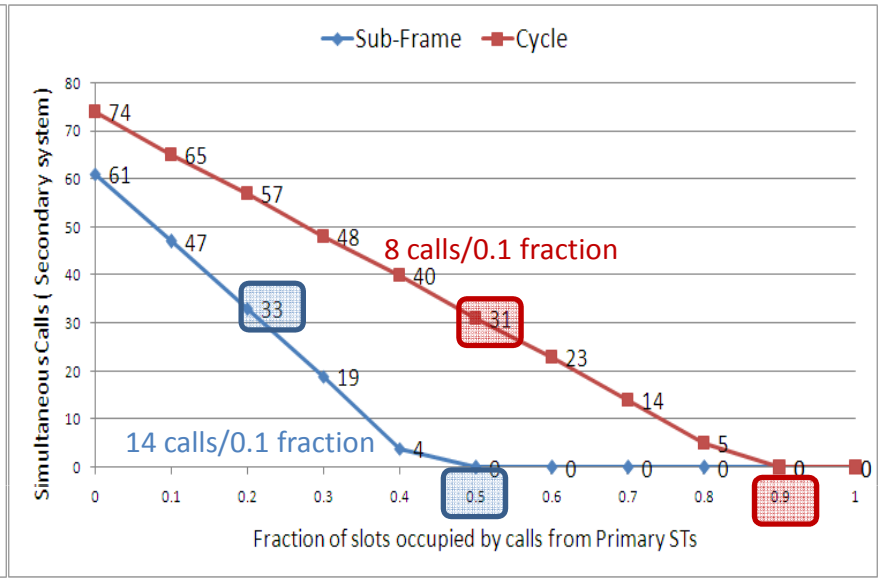
#Secondary Calls supported by different codecs for 4 hop tree with no calls from Primary

Cycle and Sub-frame scheduling scheme performing equally well

- Max. Calls from Secondary system with calls from Primary system



G.728 Codec



G.729 Codec

Number in the parenthesis indicates the fraction of slots occupied by calls from secondary system

Cycle scheme performs better than sub-frame scheme when we have calls from Primary system

Codec	Hops Supported		Simultaneous Calls		Number of	
	Sub-frame	Cycle	Sub-frame	Cycle	Sub-frames	Cycles
G.711 (64 Kbps)	5	4	0	4	2	2
G.729 (8 Kbps)	5	4	4	40	2	2
G.723.1 (6.3Kbps)	4	-	10	-	3	-
G.723.1 (5.3Kbps)	4	-	0	-	4	-
G.726 (24 Kbps)	5	4	0	15	2	2
G.728 (16 Kbps)	5	4	0	16	3	4

Sub-frame support very few or 0 calls

#Secondary Calls supported for 4 hop tree with 40% of the slots occupied by calls from Primary

Contributions & Conclusions

- Contributions :
  - Introduced and compared four different MH-WiFiRe architectures.
  - Cost analysis of two prominent MH-WiFiRe architectures.
  - Detailed description of MH-WiFiRe architecture and MAC protocol
  - Introduced and compared three different scheduling techniques
  - A tool to evaluate the performance of MH-WiFiRe.

- Conclusions :
  - MH-WiFiRe conveniently supports 2 to 3 hops typically required to extend the coverage area by 5 to 8 kms.
  - Approximate cost per village in the extended system is U.S. $ 550
  - MH-WiFiRe supports 1.6 to 3 calls per village for 4 hop architecture

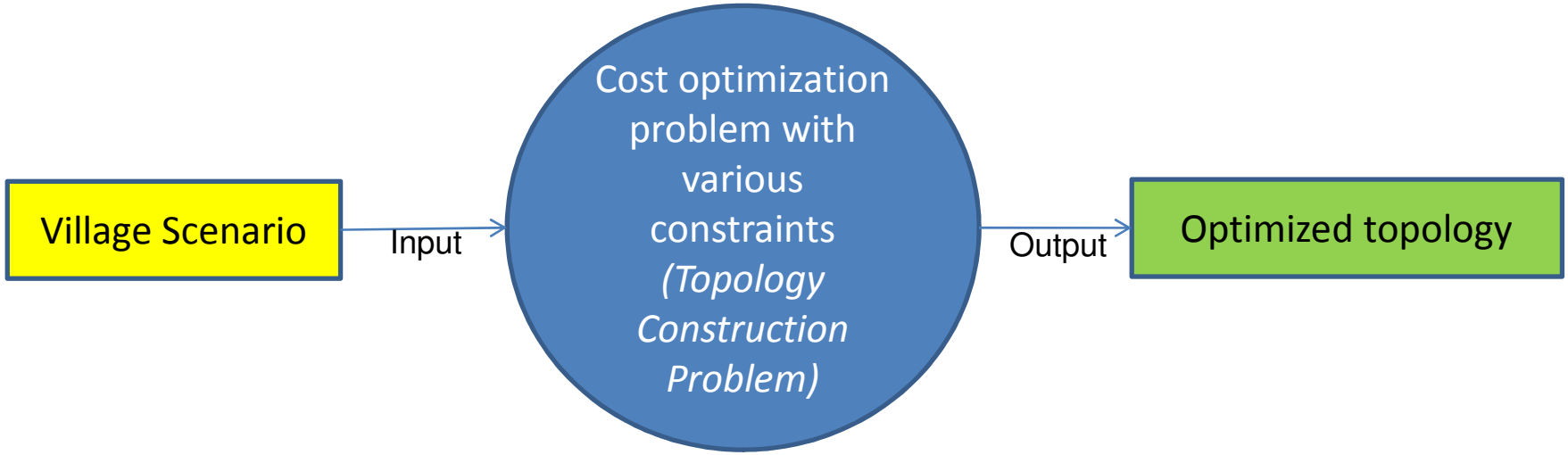
Qualitative Analysis

- Sub-frame scheme requires changes in the Primary WiFiRe frame size
- Sub-frame scheme involves more overhead slots
- Sub-frame scheme supports very few calls, when we have calls from Primary system
- Sub-frame scheme is less flexible
- End-to-end delay is less in case of sub-frame scheme is less.

Future Work

- Supporting other types of flows like rtPS, nrtPS, BES
- Transmission power assignment problem
- Scheduling based on Interference matrix
- Handling failures
- **Implementation of the protocol on hardware**
- Simulator for MH-WiFiRe
- *Cost optimization problem*

Cost optimization problem



- Topology construction is an NP-Hard problem.
- Few approximation algorithms published.
- $O(2^n)$:complexity of the algorithm, but exponent is limited to 25-30.
- Needs to be calculated only once before deployment, hence polynomial time algorithm can be used

Thank You !!!

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