WiFiNetMon

Interference Measurement in Long Distance WiFi Mesh Networks

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under the supervision of
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Motivation

- Low cost Internet connectivity for remote rural villages

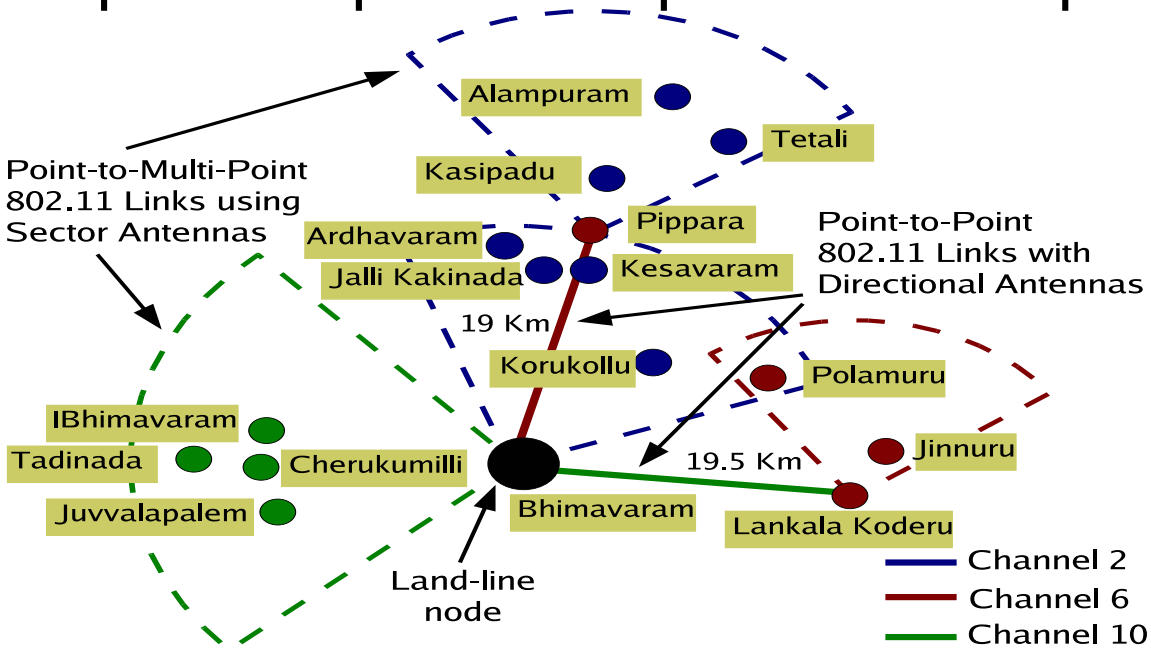
- Applications
  - E-learning in schools
  - Telemedicine
  - Livelihood skill classes
  - Interaction with domain experts

Picture taken from http://www.byrrajufoundation.org/html/ashwini.htm

- How to get network connectivity ?
  - Wired networks are costly to deploy
  - Wireless(802.11) - inexpensive hardware, widely deployed, unlicensed spectrum

Motivation

- Long distance WiFi links
  - Single point of wired connectivity
  - Use of high gain directional and sector antenna
  - point-to-point and point-to-multipoint links



Ashwini deployment as on July 2006

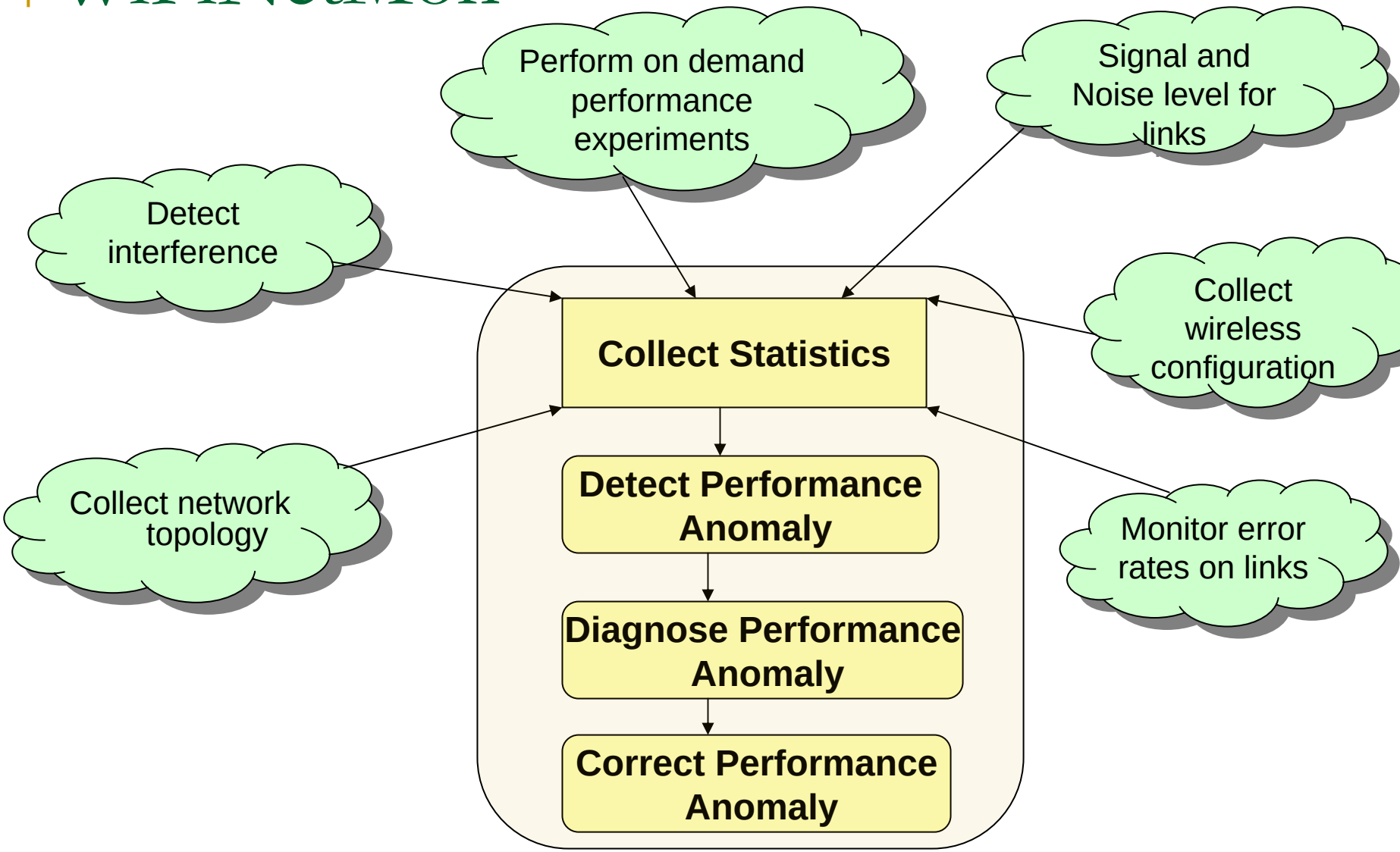
Motivation

- In Ashwini deployment
  - Channel assignment is non optimal
  - All nodes are working at maximum tx-power
  - Recent field visit in July 2006 showed very poor throughput results

- Why were results poor ?
  - Was it because of interference or …….

Difficult to answer, need statistics

WiFiNetMon


Perform on demand performance experiments
Signal and Noise level for links
Detect interference
Collect wireless configuration
Collect Statistics
Collect network topology
Monitor error rates on links
Detect Performance Anomaly
Diagnose Performance Anomaly
Correct Performance Anomaly

Our Contribution to WiFiNetMon

- Passive link monitoring
  - Signal strength and noise floor statistics
  - Bandwidth utilized
  - Data rate for packets received
- Interference measurement
  - Network interference
  - Same channel interference
  - Adjacent channel interference

Passive link monitoring

Monitored statistics	Possible diagnostic feature
Noise floor	Interference detection, Poor SNR
RSSI value	Poor SNR, Power reset
Data rate for received packets	High packet error rate

Interference measurement

Measured metric	Possible help in network management
Network interference	Optimal power assignment, Interference detection
Same channel interference	Optimal channel assignment
Adjacent channel interference	Optimal channel assignment

Challenges involved

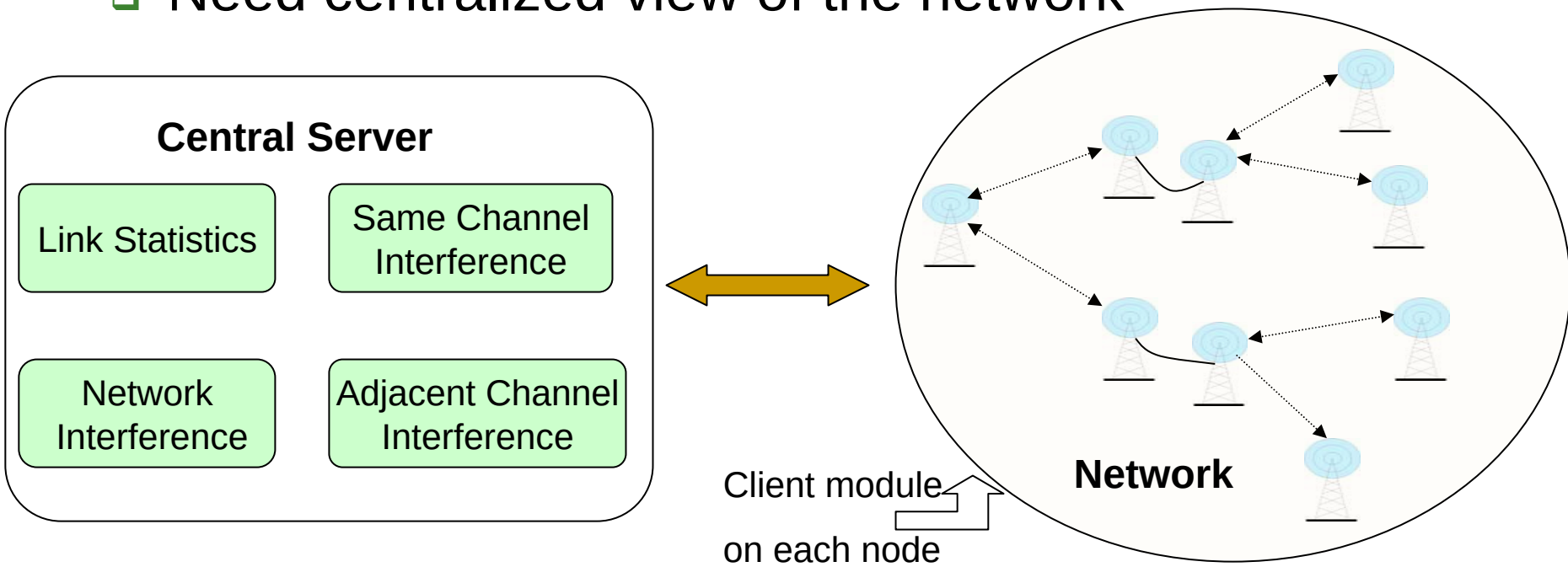
1. Low level packet details not available in user space
2. Interference ranges are longer than transmission ranges
3. Interference measurement should be as passive as possible, its not one time thing
4. Entire network up at a same time is difficult to promise
5. Design should be automated and should suit resource poor networking devices.

Assumptions

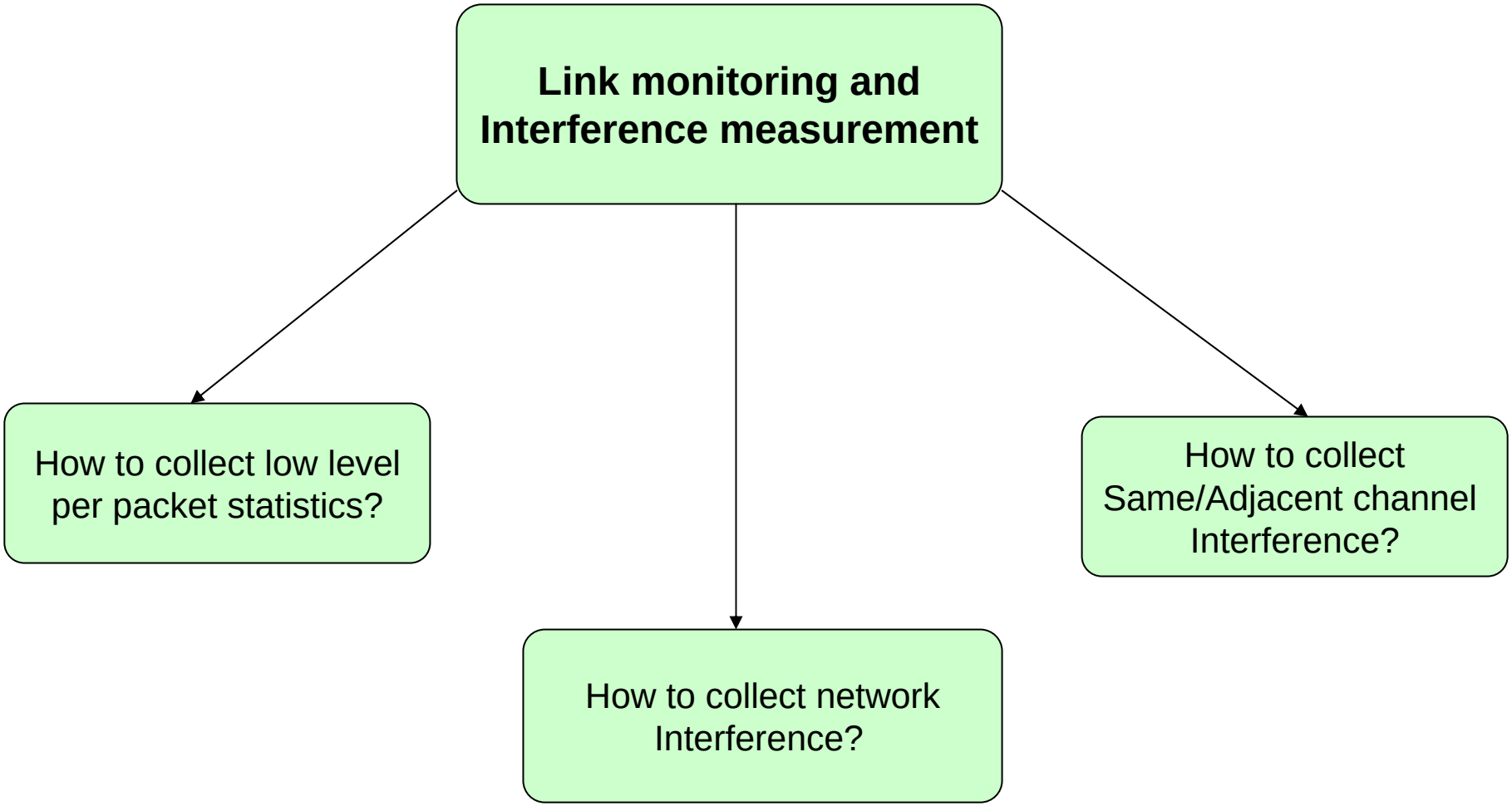
- Stable RSSI over time
- TDMA MAC
- maximum chances to detect interference
  - Maximum power
  - lowest transmit rate
  - same channel

Architecture of proposed solution

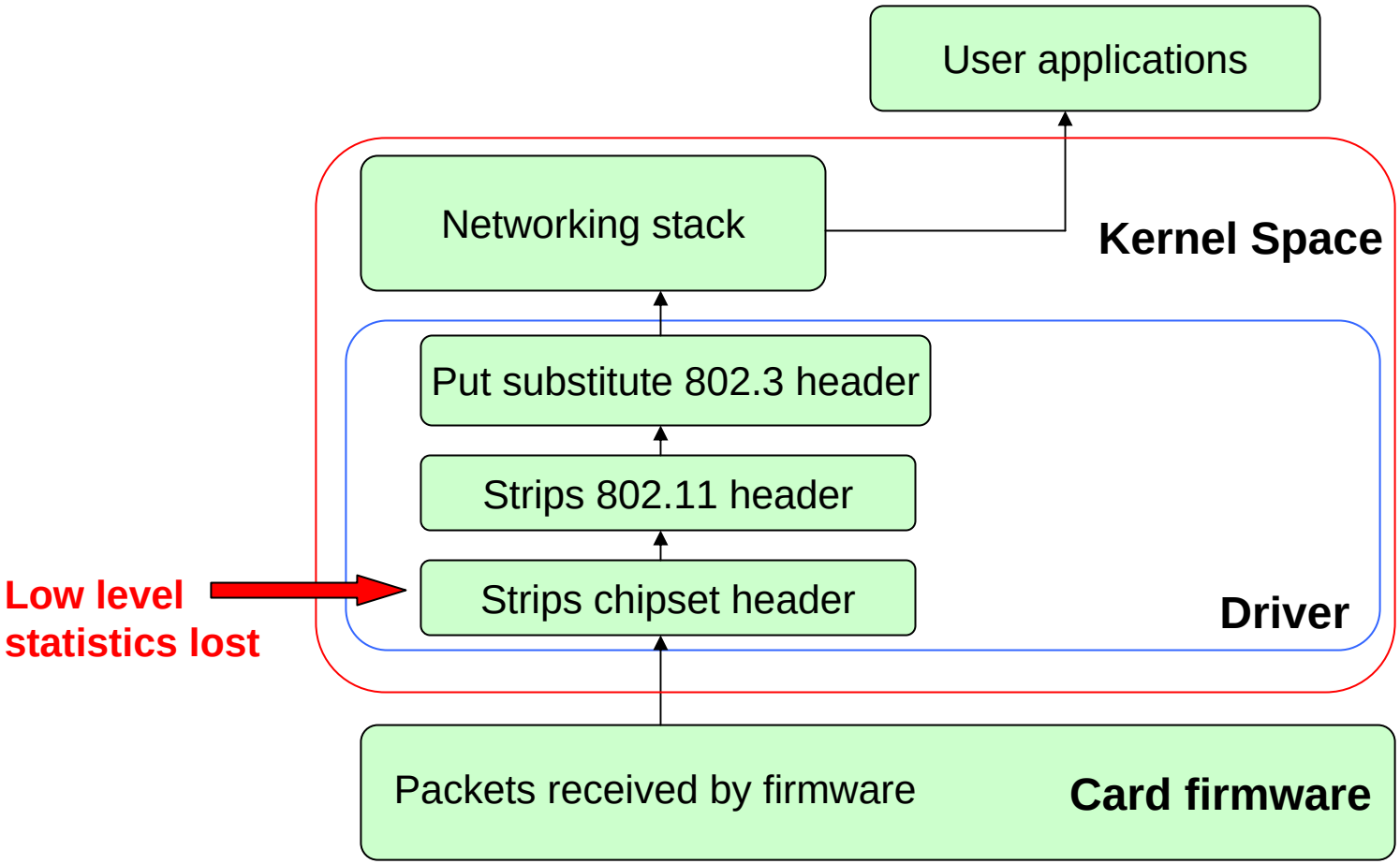
- Client-Server architecture
  - Network nodes are resource poor
  - Need centralized view of the network



Problems we seek to solve



Collecting per packet statistics



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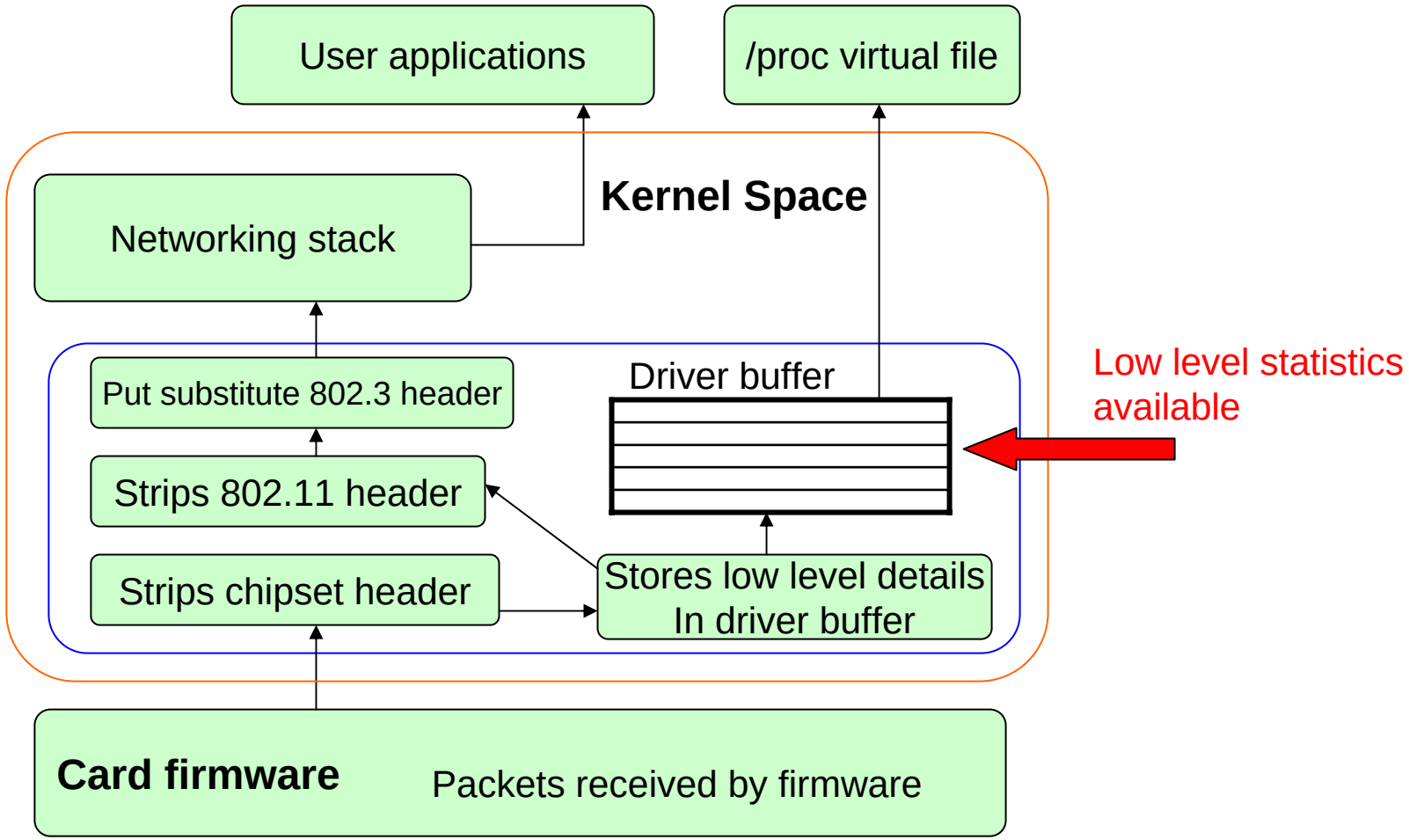

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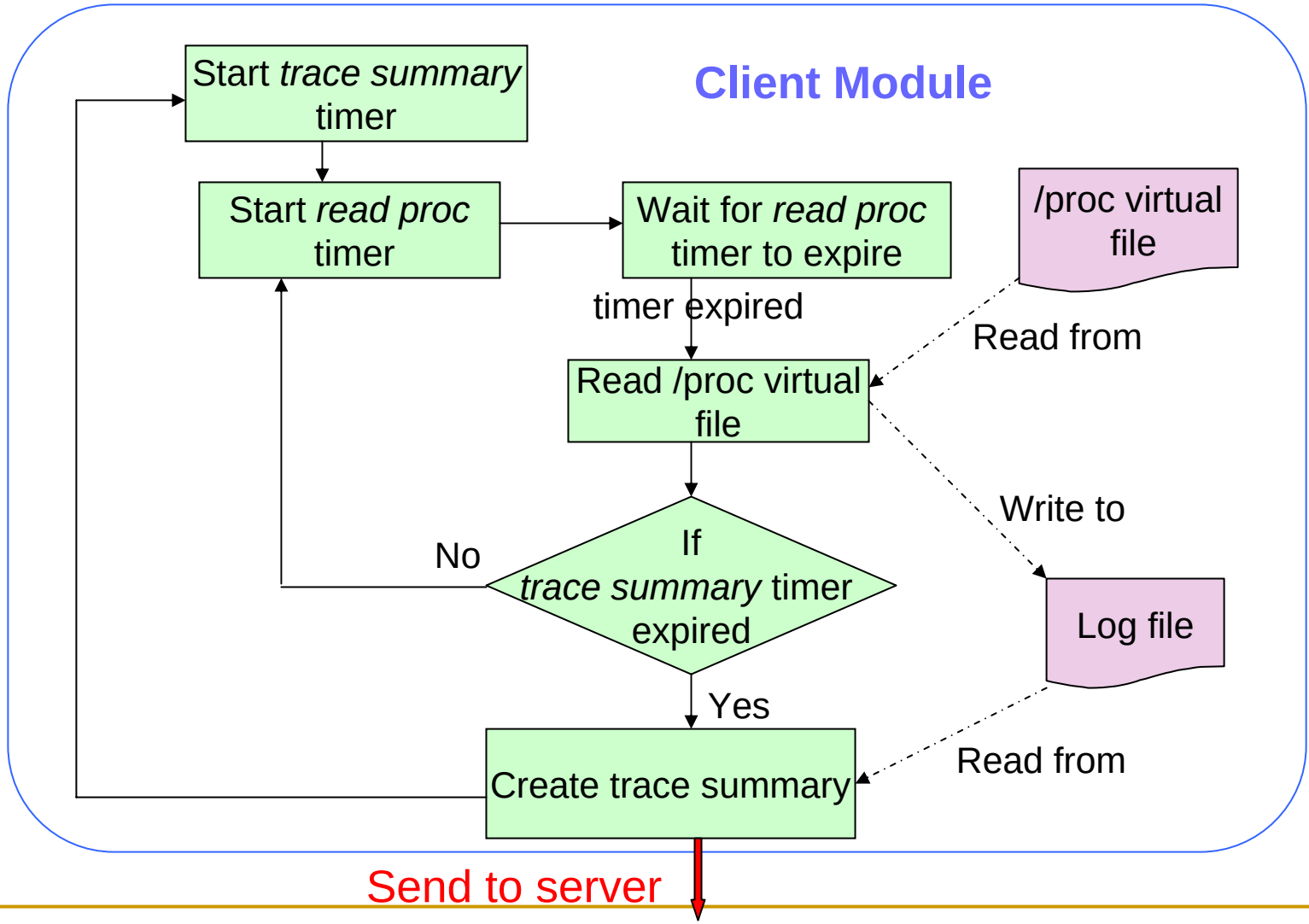
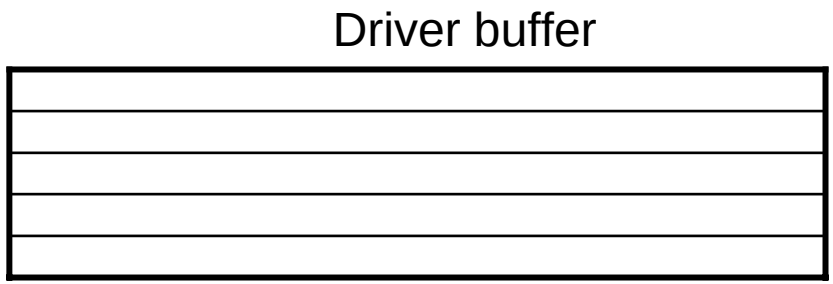


Collecting per packet statistics

- *read proc* timer depends on motive of monitoring
  - Monitoring bandwidth utilized
  - Monitoring links health
- *trace summary* timer decides how often server is updated

Measuring network interference

- Interference information from RSSI value of interfering packets is challenging because

1. 

Link packets : Present

Interfering packets : Absent

2. Interference detection possibility is maximum at lower transmit rates. So need interfering packets at lowest transmit rate.

How to ensure this ?

Measuring network interference

- Moving to monitor mode
  - Driver and firmware pass all the received packets
- But link becomes non functional
  - Radio cannot send packets in monitor mode
- Switch back to normal mode once you receive a link packet
  - Still link non functional till switch is made
  - Need a schedule for network to transmit at lower rates and to move to monitor mode

Measuring network interference

- Use of dual radios
  - Put one to monitor mode and other in normal operation mode
  - Added cost for a WiFi card
  - Use of splitters to cause signal loss
- Virtual interface in Madwifi driver
  - Create two interfaces on same hardware
  - Virtual interface not available in Hostap

Measuring network interference

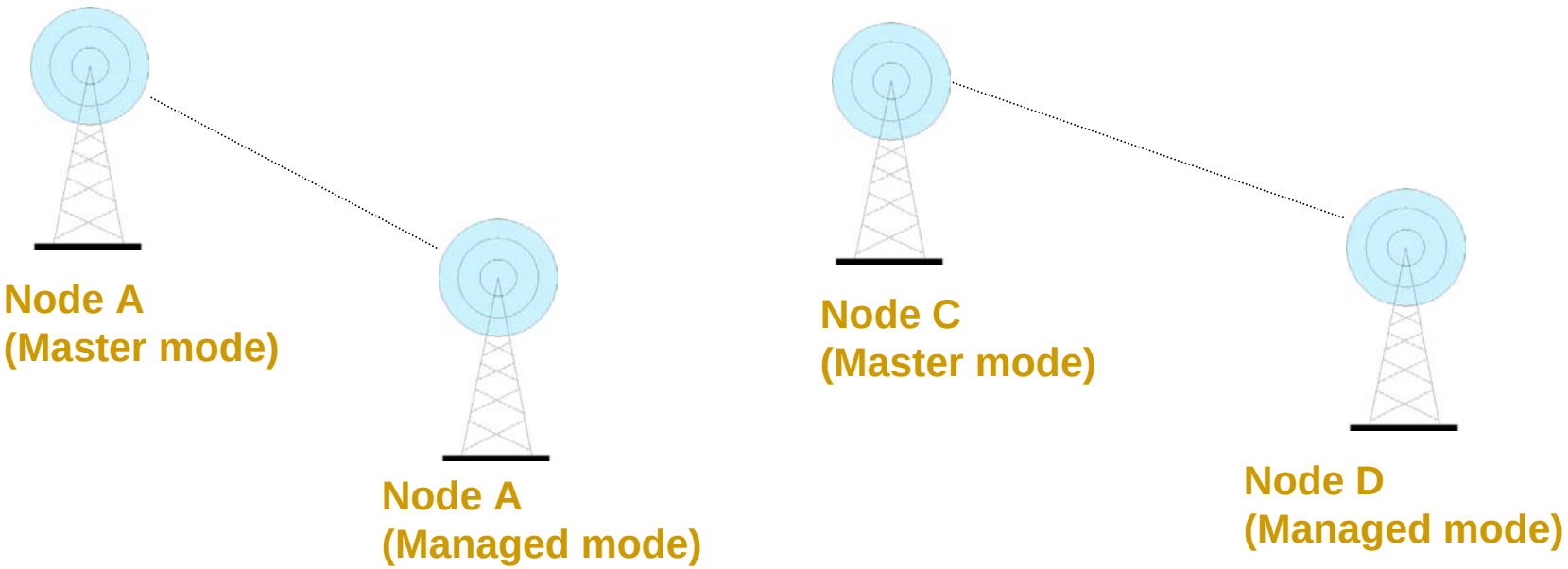
- Use of broadcast packets
  - Each node to broadcast some packets at lowest transmit rate
  - Not possible, need to have same BSSID
- Is driver modification an option?
  - No, it's the firmware dropping the packets

Measuring network interference

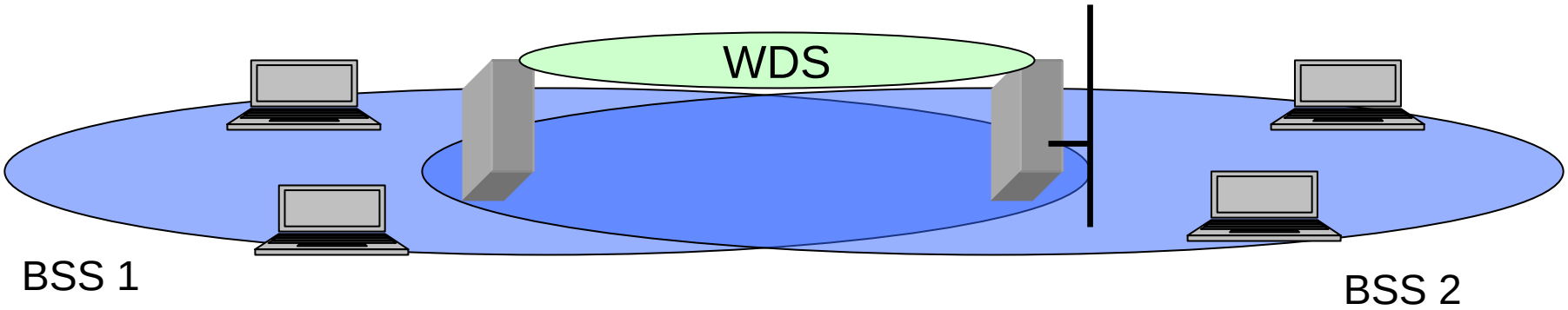
- Master mode operation
  - Can hear beacons from other Master mode nodes
  - Hearing beacons help in creating distribution system
- Are beacon packets suitable ?
  - Transmitted at lowest transmit rate
  - Small in size 88 Bytes
  - Beacon interval is configurable

Measuring network interference

- Have we solved the problem completely?
  - No, beacon packets will be heard from Master mode devices only



Measuring network interference

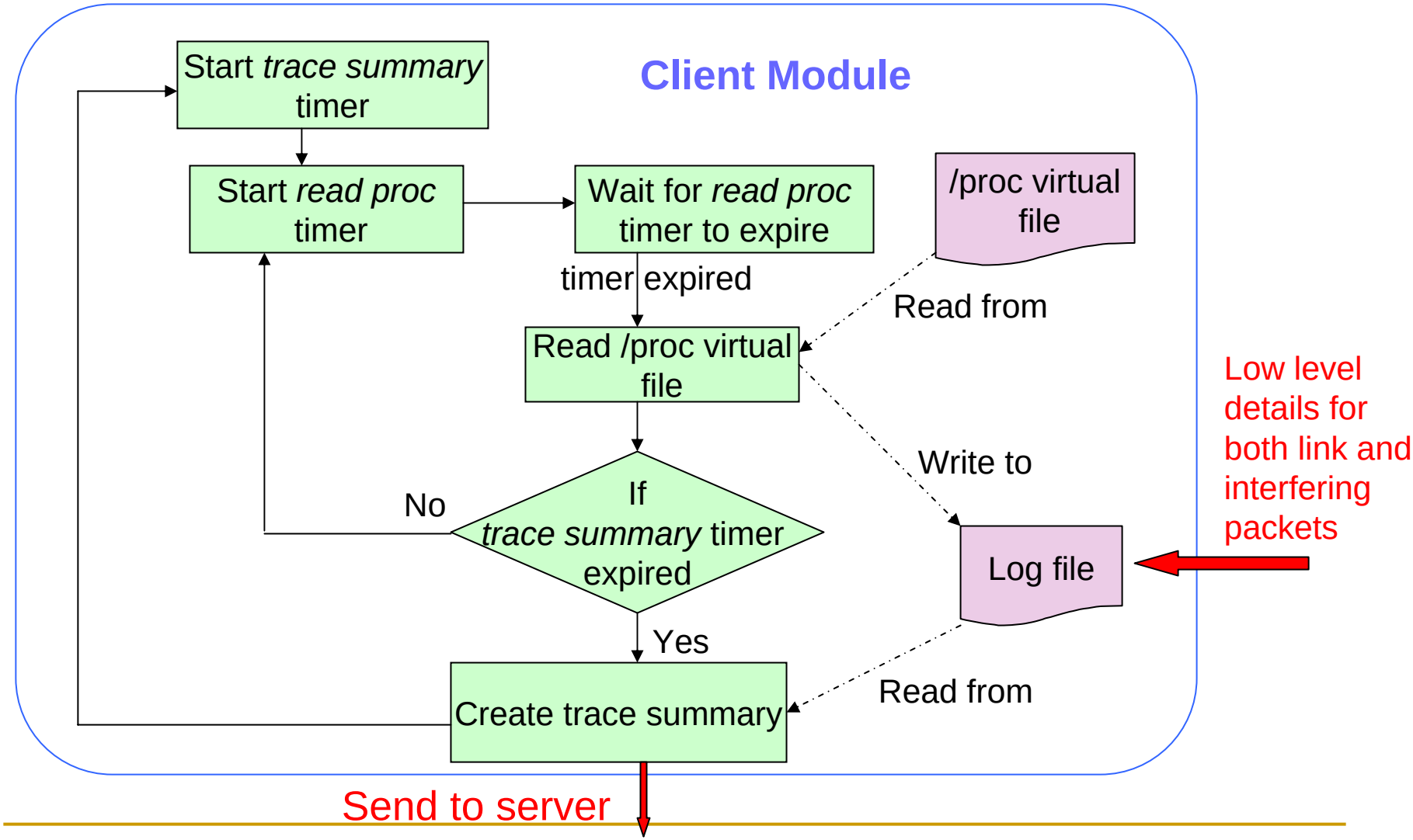


- In WDS two Master mode devices can create a link

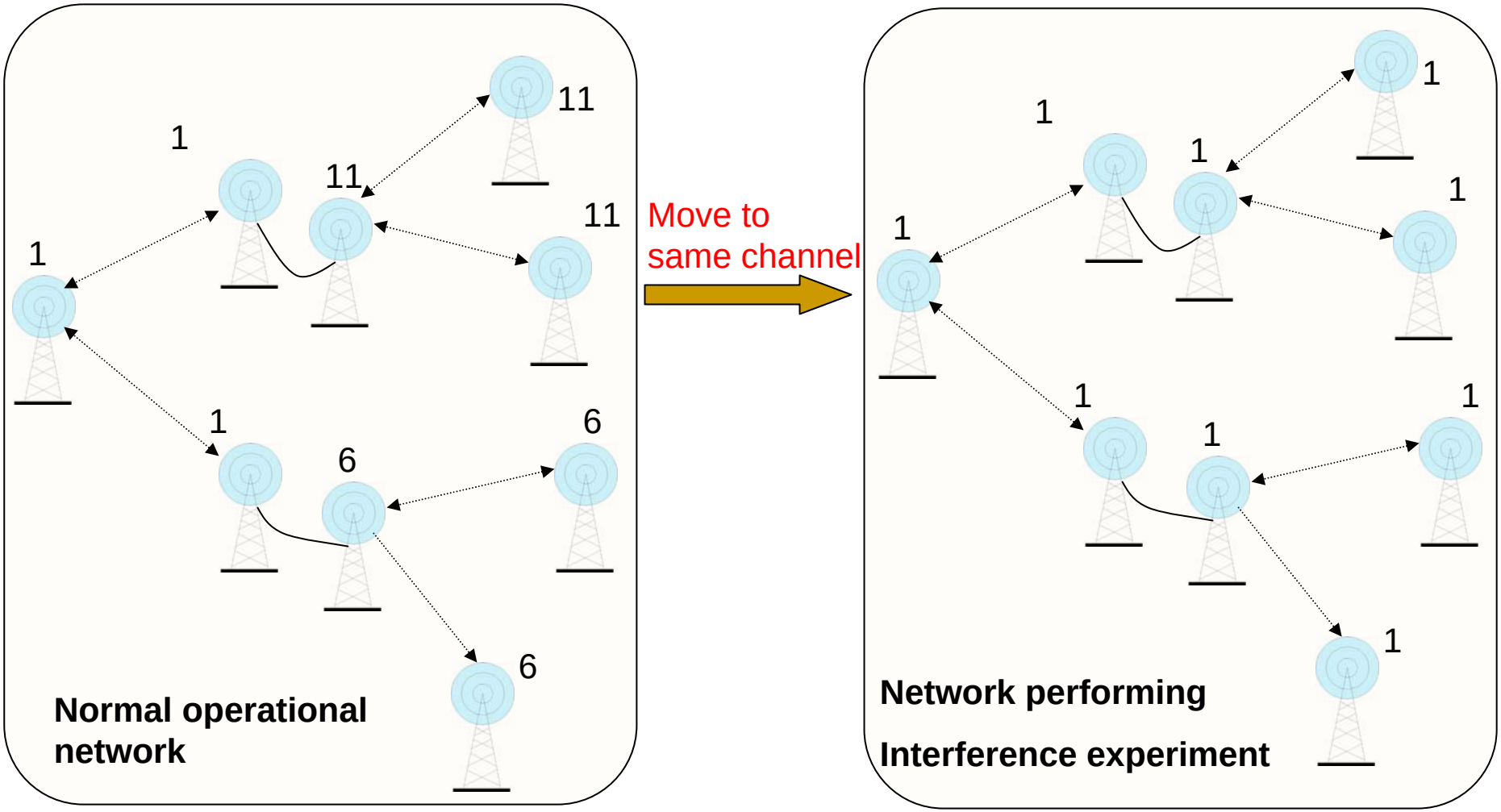
What about point-to-multipoint links?

- Multiple WDS connection with same Master node possible

Measuring network interference



Measuring same/adjacent channel interference

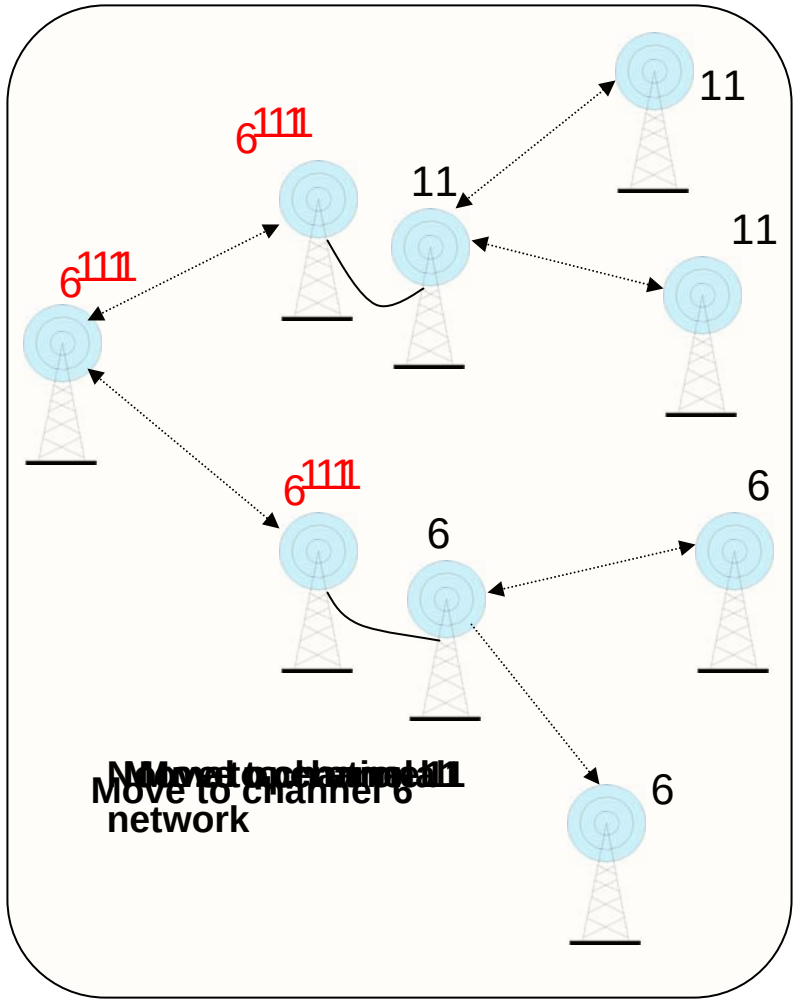


All at the same time approach

Measuring same/adjacent channel interference

- All at the same time approach
  - Network mostly non functional during experiment
  - Measurement is not one time thing
    - Link misalignments
    - New links added in deployment
  - Entire network being up is difficult to guarantee

Measuring same/adjacent channel interference



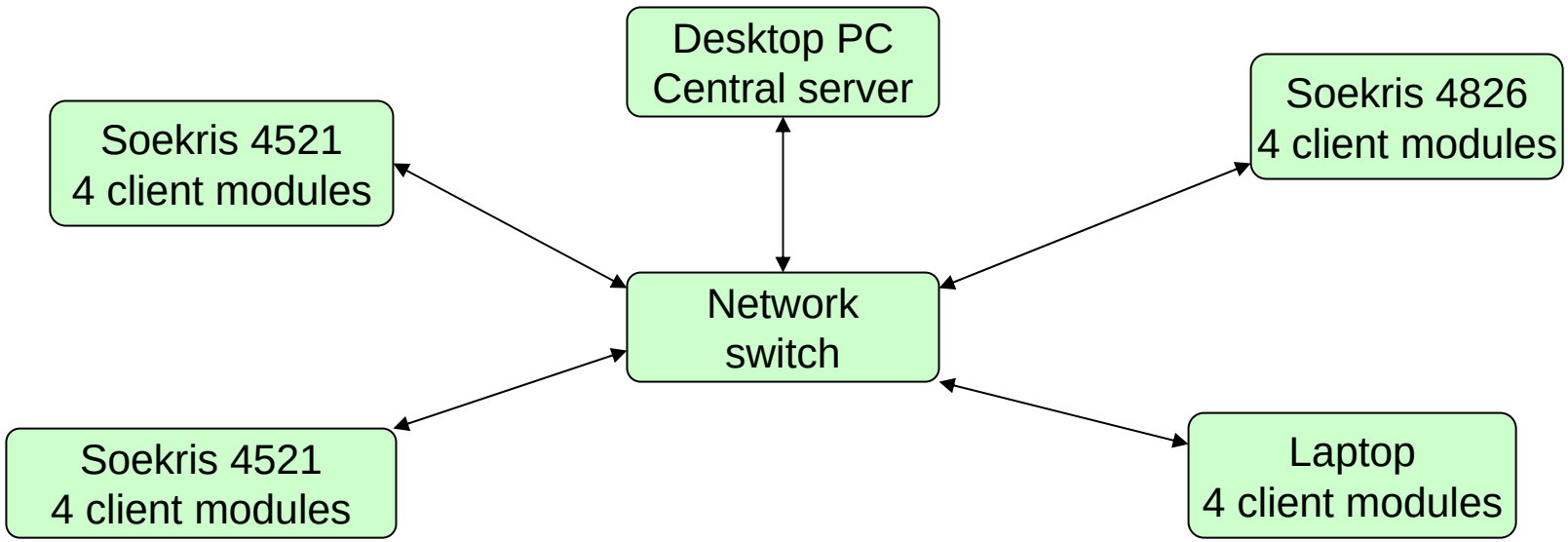
One at a time approach

Measuring same/adjacent channel interference

- After experiment with a group
  - Network has information about interference from group
  - The group has information about interference from network
- Central server keeps track of nodes having incomplete interference information
- Time synchronization between nodes using NTP

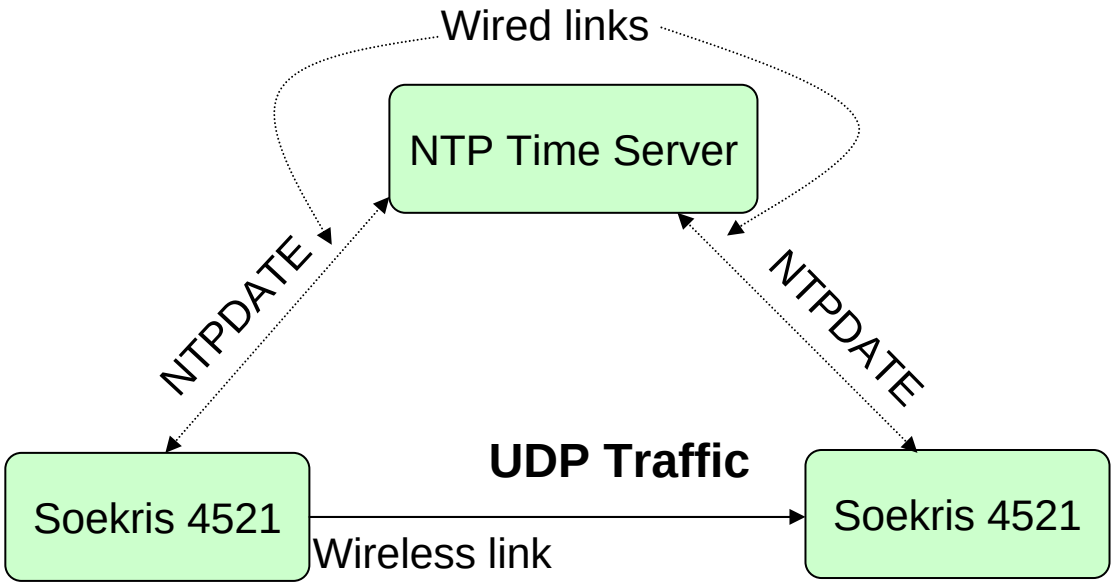
Evaluation

- Emulation study
  - Physical network up to 4 nodes only
  - Physical network for larger number is cumbersome
  - Emulation over Soekris machines for 8 and 16 node network



Evaluation

- Channel switching overhead
  - Overhead involved in same/adjacent channel interference experiment



- **Mac broadcast**
- **UDP traffic**
- **Link operating at 1Mbps in WDS setting**
- **UDP packet size of 1000 bytes**
- **Inter packet duration of 10 milli seconds**

Evaluation

Experiment Number	No. of packets lost	Link non functional duration (milli seconds)
1	47	470
2	78	780
3	72	720
4	70	700
5	21	210
6	68	680
7	68	680
8	74	740
9	6	60
10	67	670
Average Value	**57**	**570**

Evaluation

- Network overhead
  - Network occupancy by trace summary messages
  - Network occupancy by beacon packets

- Trace summary message overhead
  - Assuming size of 10 KBytes for trace summary
  - For 20 node network, 1Mbps tx-rate, trace summary interval 10 minutes

Trace summary overhead less than 0.3% of available bandwidth

Evaluation

- Beacon packet overhead
  - Beacon packet size 88 bytes
  - Beacon interval 100 milli seconds, With 10 minute trace summary interval there is opportunity of hearing 6000 interfering packets from each other node
  - Considering Ashwini topology, average members per group is about 4
- Network overhead by beacon packets will be 2.8% of available bandwidth
- If beacon interval of 1000 milli second is chosen than this overhead reduces to 0.28%

Evaluation

- CPU utilization
  - Read proc duration of 5 milli seconds
  - UDP traffic 1000 Bytes packets size
  - Used MAC broadcast

Inter packet duration (milli seconds)	CPU utilization for Soekris 4521	CPU utilization for Soekris 4826
0	41%	39%
10	12%	10%

Evaluation

- Time taken to create same/adjacent channel interference matrix
  - Depends on
    - Experiment duration per channel → 1 minute
    - Number of groups in the network → 6 (in Ashwini)
    - Timeout interval and guard time → 30 seconds, 1 minute
- Total time taken to create interference matrix from scratch is 30 minutes

Future work

- To test the designed solution rigorously
- To use collected statistics in performance anomaly detection and diagnosis
- To use collected interference values as heuristics for better power and channel assignment
- To explore possibility of reducing CPU utilization

Conclusion

- Designed, implemented and evaluated solution for
  - Link monitoring
  - Interference measurement
- Network overhead low
- Network non functional duration negligible
- CPU utilization on higher side

Questions ?