Multihop on WBHF

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KNL

- Founded 2011 as spin-off from Centre for Wireless Communications, University of Oulu

- Bought by Telenor Group 2020 because of KNL maritime business utilizing CNHF WBHF radio and IOT edge computing, name changed to Telenor Maritime

- Defence business carved out as own business in 2022 and rebranded back to KNL. 100% owned by Telenor Group (Norway)

Motivation for multihop

- Non-ideal antennas, radiation patterns, skip zones etc.
- Propagation especially in north during winter nights extremely challenging and also highly variable
- Local variation in propagation as seen from CNHF sounding data from KNL test network
- Connectivity in the network is time-variant and not predictable
- *Increases the high quality surface wave range -> higher data rate, higher reliability, EW protection*

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Opportunities

- Modern WBHF SDR platforms can listen multiple frequencies at the same time
- This enables faster linking but also much more efficient sounding
- Efficient sounding gives important information about the channel conditions and what nodes in the network can be reached on what part of spectrum
- Sounding gives also information about the network connectivity
- Efficient sounding combined with high performance SDR platform eases up propagation prediction and frequency planning

- Based on CNHF sounding data multihop capability would dramatically increase the overall connectivity in the network

- We can see the same phenomenon in maritime mesh network where not all base stations can hear all the ships at the same time, but some base stations can hear some of the ships all the time i.e. there is almost 100% connectivity all the time

Requirements for Multihop on HF

- Adaptive, as network topology changes all the time because of propagation changes
- Adaptive, as link quality is most likely not similar between source, relay and destination
- Automatic, as users have other things to do than relay messages or other data manually
- Scalable, as network can have hundreds of nodes
- Must be used only when required
- Must cause minimum overhead

Reactive or proactive routing?

- Reactive: multihop routes are found out when required (example: AODV)
- Proactive: multihop routes are kept up to date even of there is no need for them (example: OLSR)
- As in most of the cases direct link exists, reactive is obvious choice

Requirements for radio platform and waveform

- Multi-channel RX to enable efficient sounding
- Fast broadcasting capability for route requests
- Fast linking for enabling adaptation in changing conditions (frequency, bandwidth, modulation, coding)
- Spectrum sensing capability to avoid other friendly transmissions and avoid interference
- Capability to efficiently utilize sounding and spectrum information when choosing frequencies for connections
- WF must be capable handling of asymmetrical links when relaying
- End to end ack to assure data delivery
- RTS, CTS, DATA and ACK can all happen on different frequencies on S-R and R-D links because of propagation or local interference -> extreme frequency agility required

CNHF Multihop

CNHF SDR platform

- Wide band HF radio platform
- By definition ideal software defined radio platform
- Currently two form factors:
  - CNHF1, rack mountable hw, 1.5-30MHz, 250W TX power
  - CNHF Manpack, small form factor, 1.5-56 MHz, 25 W TX power
- Listens over 2500 calling channels at the same time (over 4000 for CNHF Manpack)
  - Handshaking can start at any time at any channel -> asynchronous system, no need for GNSS or other time reference
- Can operate in multiple modes at the same time:
  - CNHF Normal Mode: wideband, extremely fast linking and sounding (CNHF - CNHF)
  - CNHF Robust Mode: narrowband, extremely robust (CNHF - CNHF or CNHF -Legacy HF with CNHF-ID)
- Spectrum sensing and cognitive spectrum usage

- Both platforms share the same fully digital SDR architecture
- Processing on FPGA & CPU
- Extremely flexible platform enabling both single and multicarrier operation
- Both radios run the same CNHF Waveform and are interoperable
  - Modern SDR WF architecture: Full protocol stack from PHY to NET including TRANSEC (AES256)
- Built-in SMTP and XMPP servers /w standard external interfaces
- WebUI w/ email and IM clients
- BW up to 48 kHz (CNHF1), 96 kHz (CNHF-MP)

- *Currently no STANAG WFs implemented*
  - *We plan to implement HAWCS as soon as there is something to implement*

CNHF1

CNHF-MP

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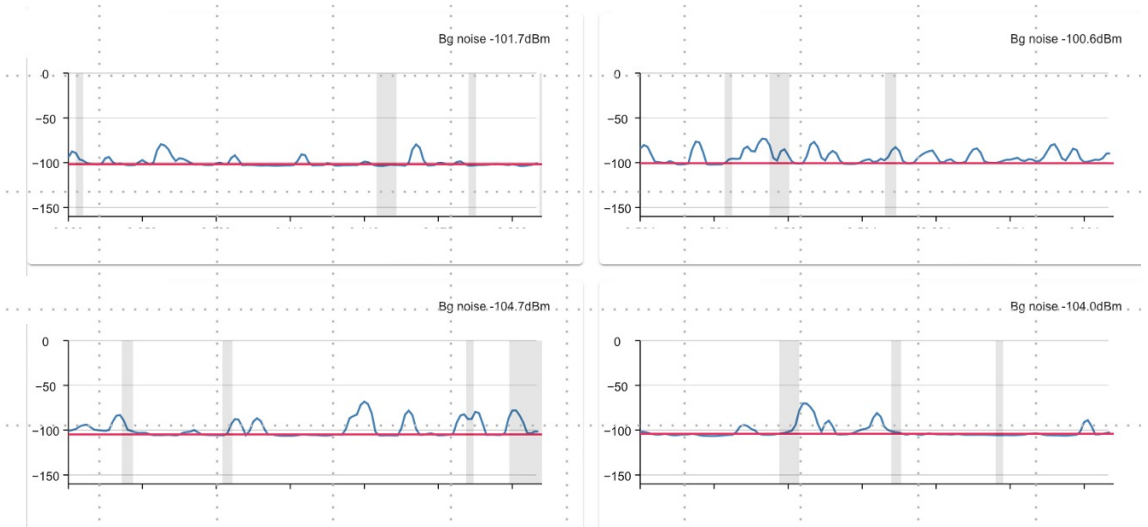
CNHF WF Sounding

- Each node in network broadcasts pseudorandomly very short sounding messages (Frequency Message, FM) containing sender address, location, timestamp and information about the background noise level on that part of spectrum
- Based on these nodes gain information about connectivity and on which part of spectrum it is best to establish links to which nodes
- In addition each node does continuous spectrum sensing and estimates background noise level on each part of spectrum

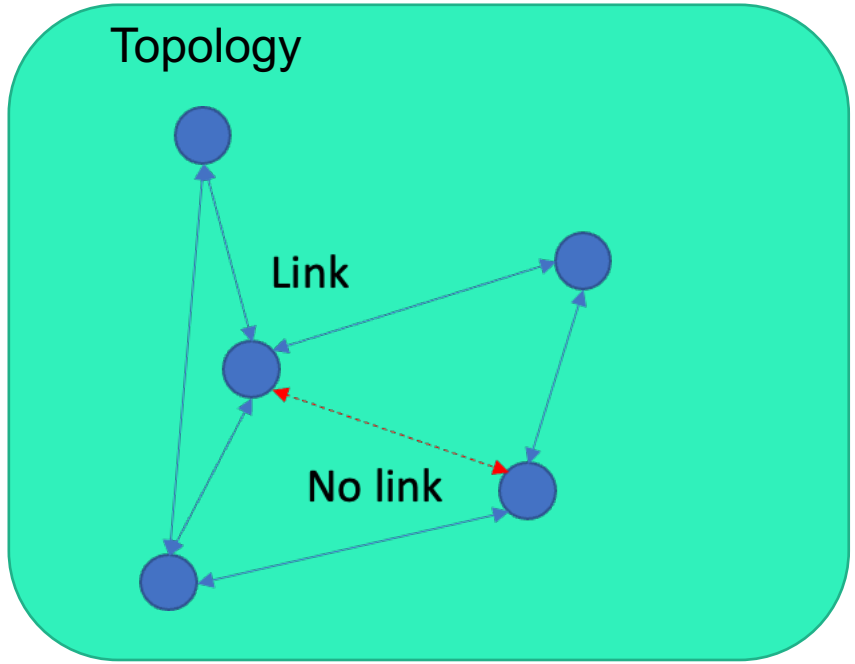


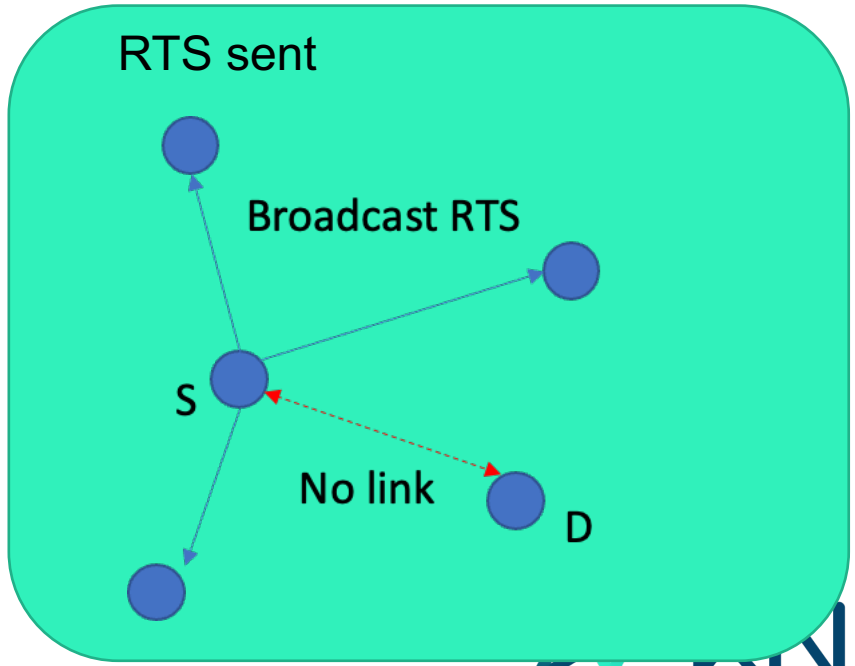
CNHF WF Linking

- In linking, RTS frequency is chosen by sounding info from destination taking into account the local spectrum
  - In RTS, required QoS is signaled as well as ACK frequency
- In CTS, destination signals transmission parameters and frequency for data transmission
  - Parameters chosen based on estimated link quality and required QoS
- Linking can start at any time on any of the calling channels
  - No wait time to be in correct part of frequencies
  - Extremely fast linking as no need for long linking calls before RTS
  - No need for GPS or other network time synchronization

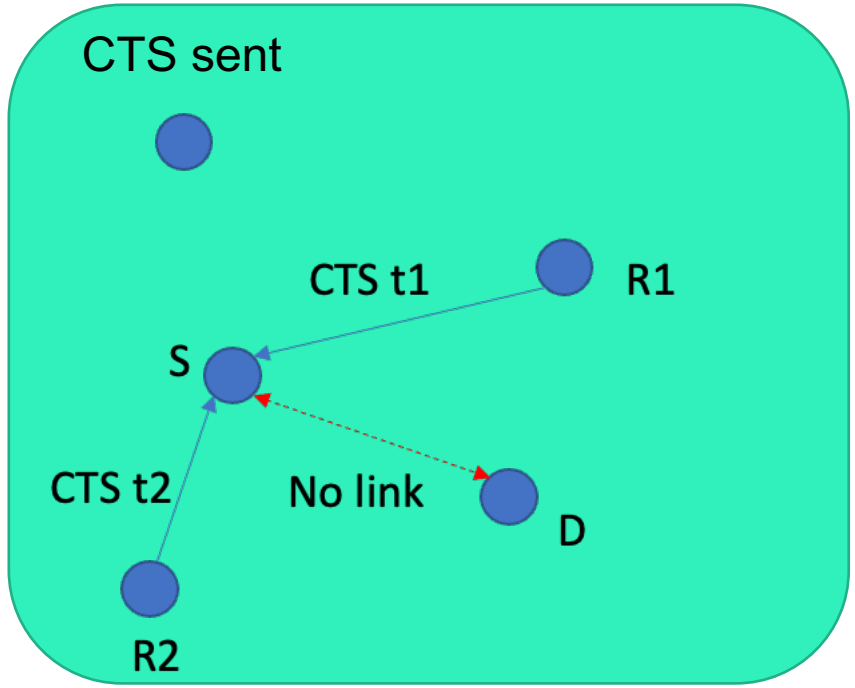
Multihop on CNHF WF

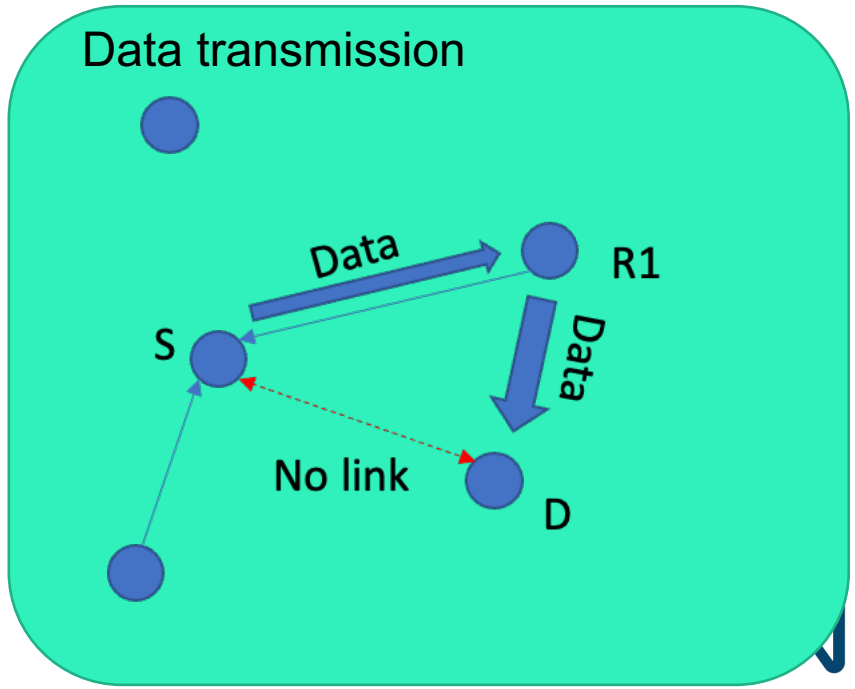
- Based on sounding information nodes know what other nodes they have connectivity
- In case Source does not have connectivity to Destination, it sends Broadcast RTS where it asks route to Destination
- Relay nodes with connectivity to Destination respond with CTS
- Reactive routing protocol, as multihop routes are found only when required
- Supports currently using one relaying node (two-hop)
- Implemented and available as SW option to CNHF radios





- During route establishment links are negotiated normally, i.e. transmission parameters and used frequencies can (and usually are) different on different links
- During data transmission links are ACKed per link and links support all the normal CNHF WF capabilities (ARQ, link maintenance, link renegotiation)
- If link from relay to destination drops, route establishment is restarted
- When new route is established, transmission continues from where it dropped

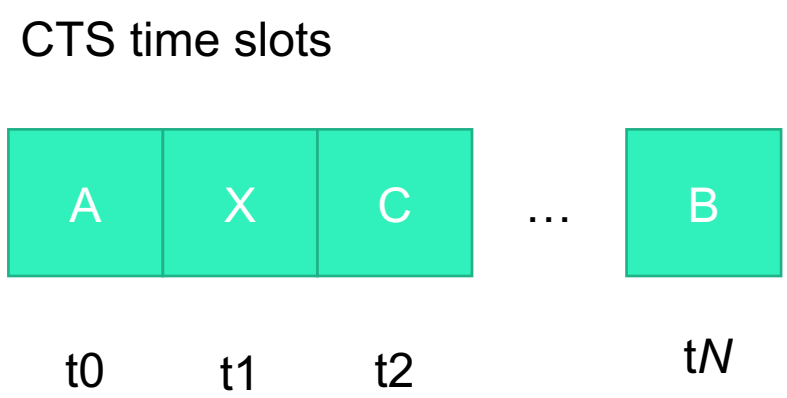


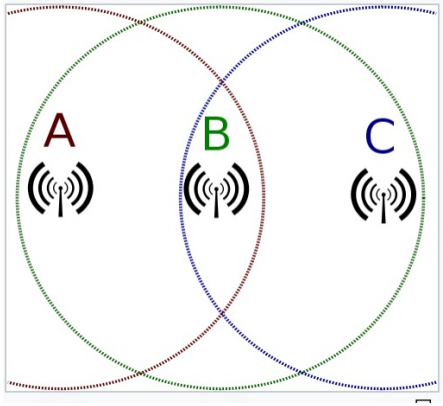


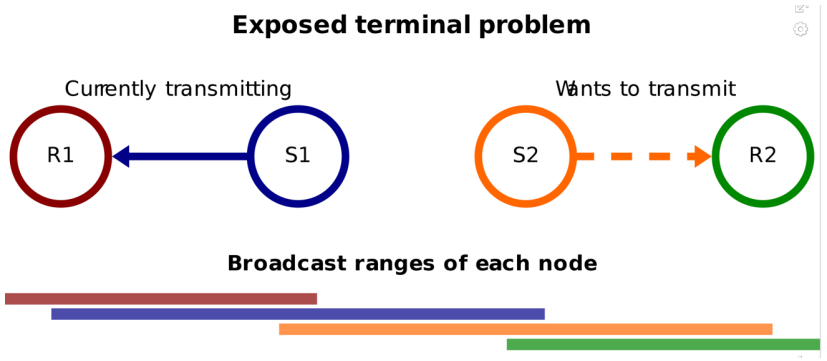
CTS collision avoidance

- CTS collision avoidance based on time slots which are chosen based on link quality from Source to Relay and to Destination, i.e. relay node with good total link quality sends CTS before one with poor total link quality
- Total link quality is estimated based on RTS and FM quality and relevant background noise level
- Reduces significantly collisions as

Relay A, LQ=96
Relay B, LQ=43
Relay C, LQ =71
…
Relay X = 91







Hidden node problem

- Well known problem with single channel ad hoc networking
- By nature part of HF networks so multihop does not make the situation worse
- Number of calling channels and fast linking of CNHF can listen simultaneously mitigate the problem, as it is unlikely that both A and B will send RTS on same channel at the same time

Exposed node problem

- Well known problem with single channel ad hoc networking
- Cognitive spectrum usage eases up the problem, as all the nodes try to avoid other transmissions and hence should be able to find free space in spectrum for communications

Current Status

- Multihop is implemented as software option to CNHF WF
- Automatic 24/7 OTA testing in in KNL test network in Finland
- Test results to be analyzed, initial results very promising: connectivity is increased and better bit rates can be used
- Performance optimization

Way forward

- Consider if there is a need for third hop -> would increase usable the surface wave range

Questions?