An Innovative SDR Architecture and MANET with Simultaneous Multiple Channel Reception

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2013 Wireless Innovation Forum Conference
On Communications Technologies and Software Defined Radio
Washington DC. (USA) 8-10 January 2013

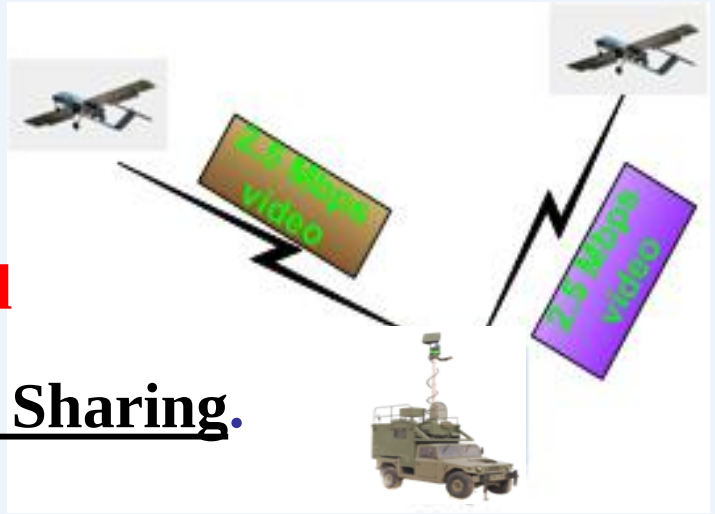
Outline

- Multi-Channel Reception (MCR)
  - The Receiver Bottleneck Problem
  - MCR advantages over Stacked Networks
- SDR Architecture
  - The HW Platform
  - Network and MAC
- SDR Highlights

The Receiver Bottleneck: 1-Channel TDMA

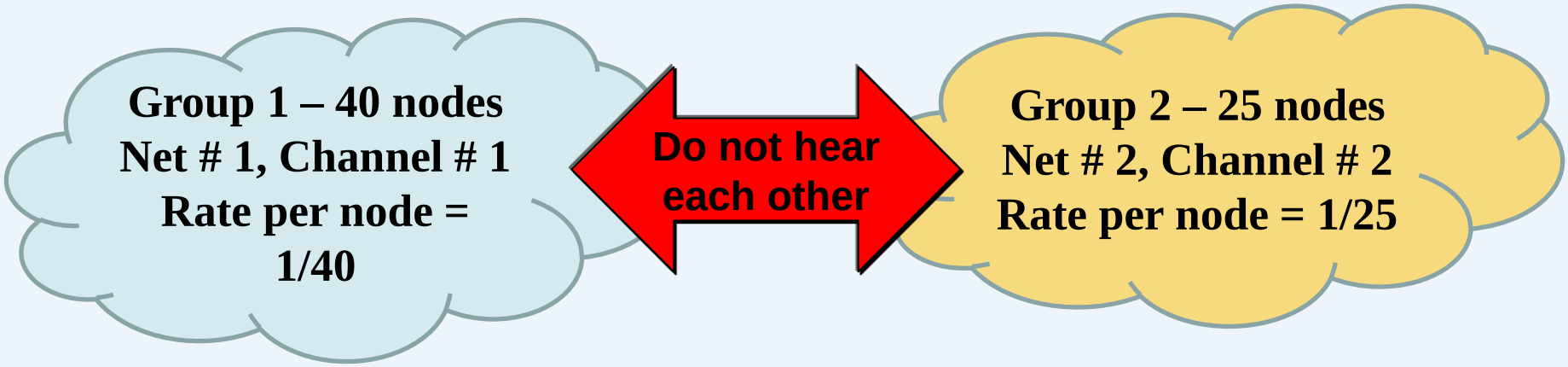
RX rate is 5 Mb/sec

Total RX rate is still 5 Mb/sec
Thus the TX rate must be lowered



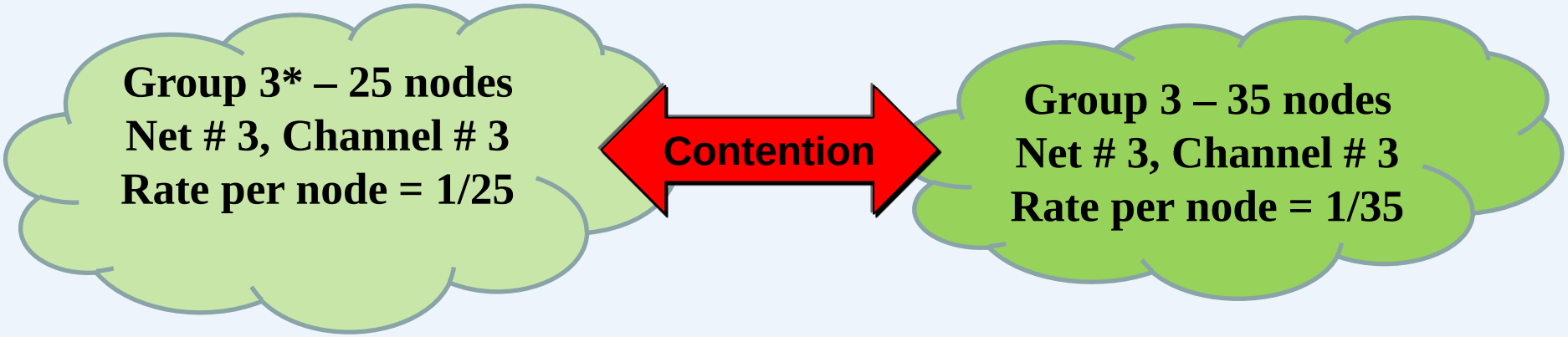
Reception of 2 Video Sources: Time Sharing.

Merge, Pass-through & Split Groups



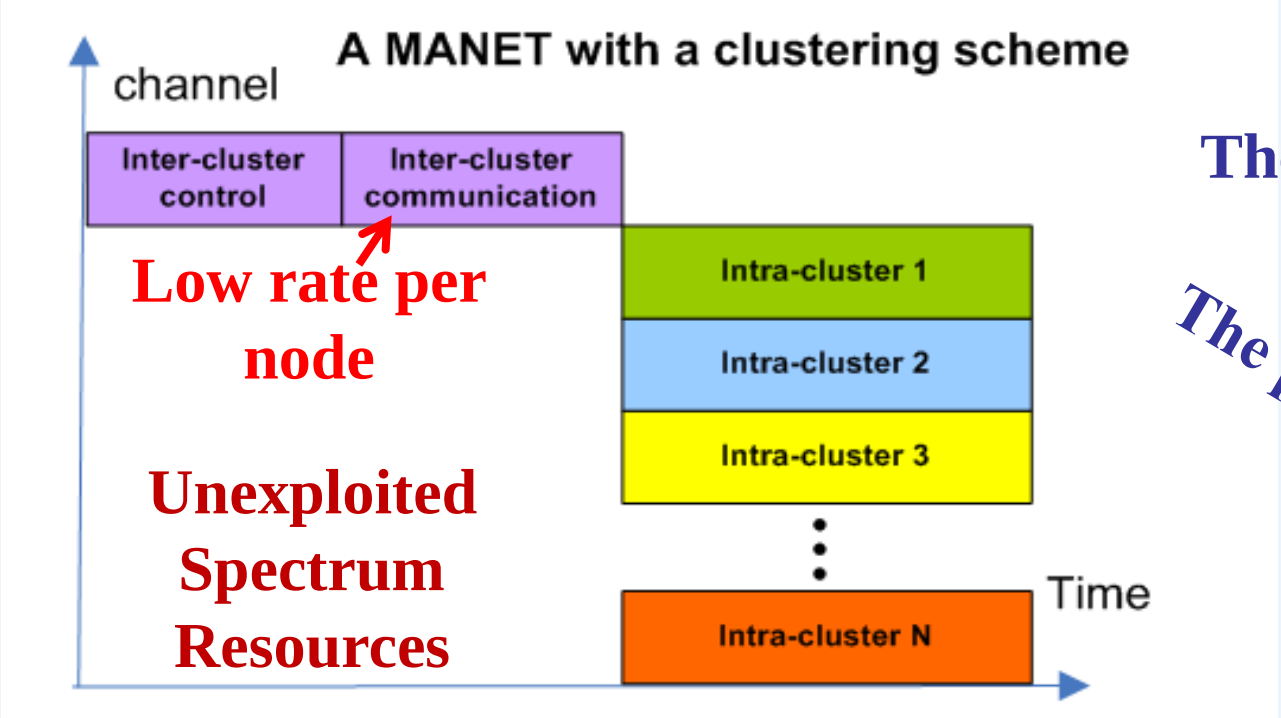
- The “Receiver Bottleneck” poses severe scalability challenges for 1-channel TDMA networks
- Even if manually configured, the per node rate significantly drops

Merge, Pass-through & Split Groups



- Mitigation of the problems, arising from the Receiver Bottleneck, require:
  - Complex algorithms
  - Special resource pre-allocation for control traffic and inter-group communications

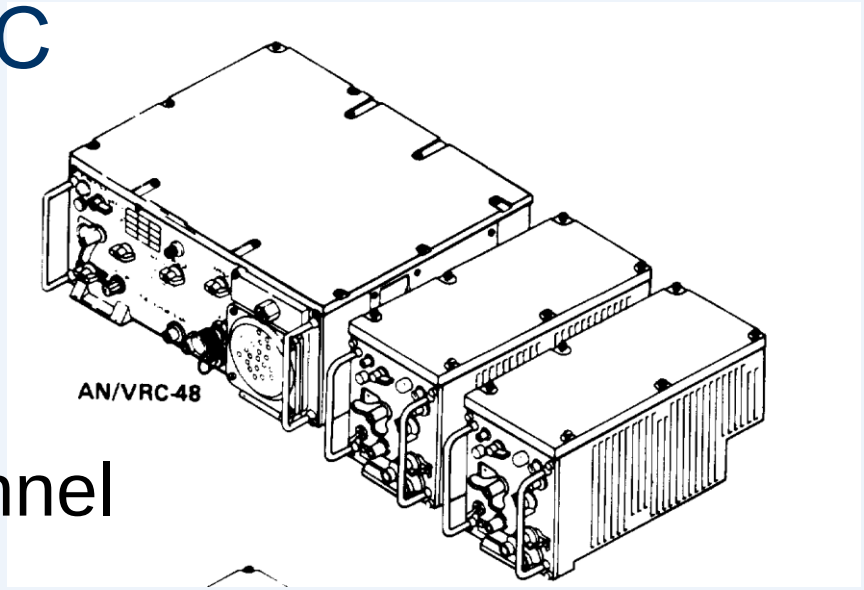
Mitigating The Problem



- 1-Ch TDMA leads to a low per node update rate for inter-group (“common”) communications
- Information on “private” channels is limited to members only

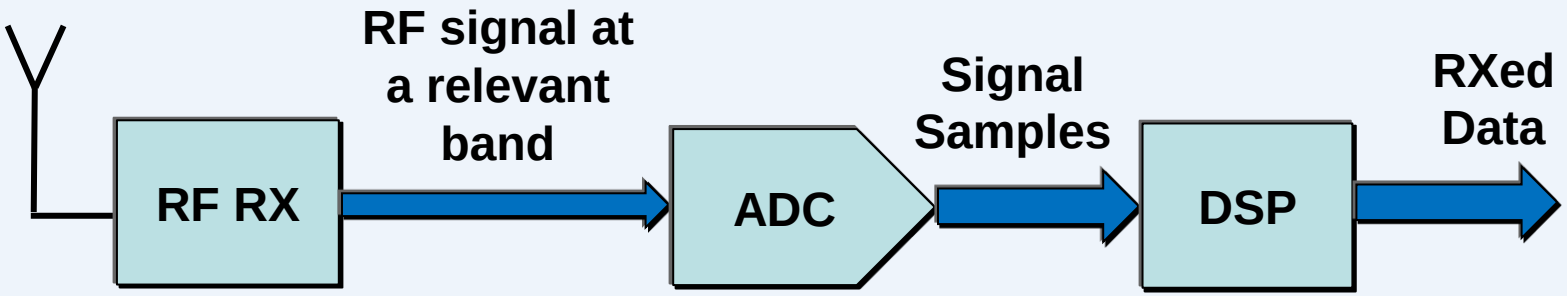
Overcoming The RX Bottleneck

- The commander's VRC
  - One transceiver
  - + Two receivers
- Modern analogy
  - TX at any chosen channel
  - RX all the channels
- Reception during transmission is implementation dependent
  - Full or Half Duplex radio



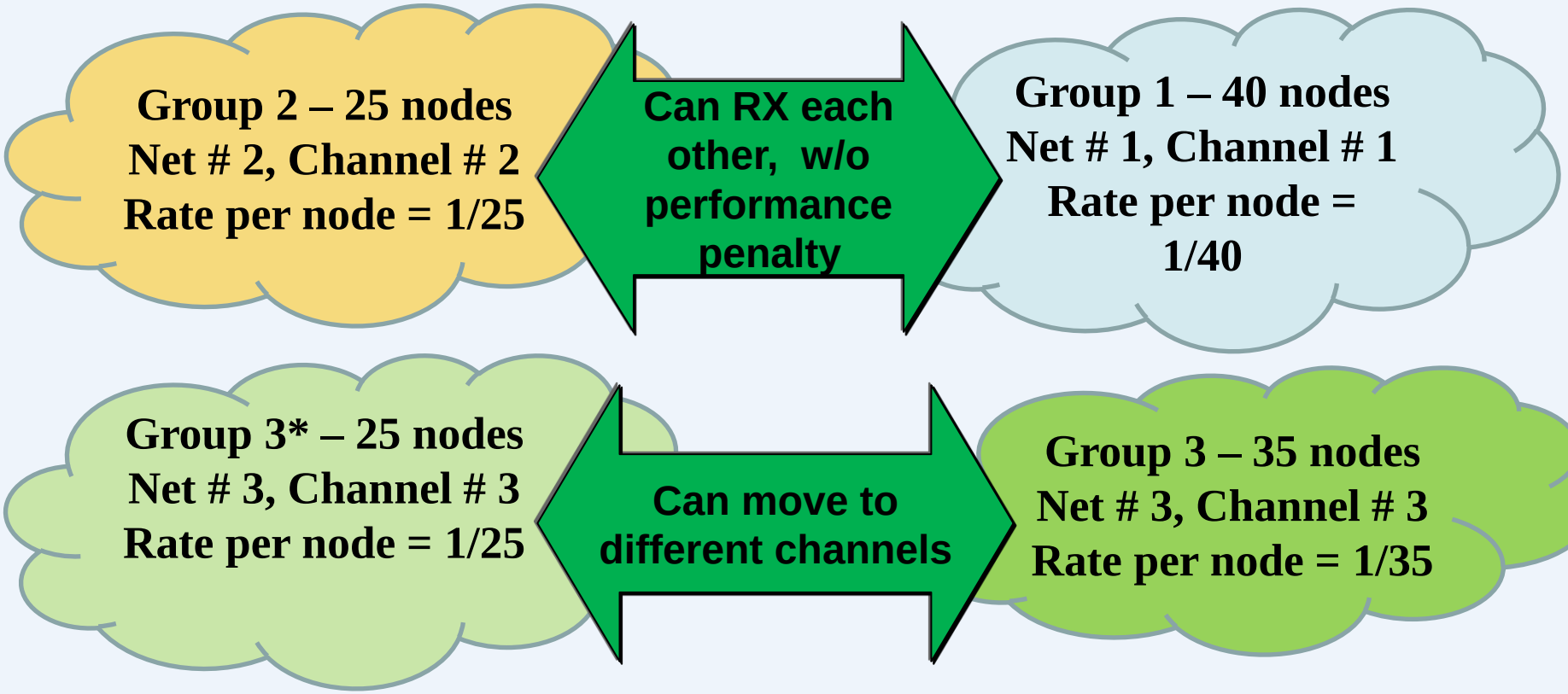
Implementing MCR

- Adding physical RX heads each tuned to a different channel
- Use a single wideband RF reception module ending with an ultra-fast ADC
  - Perform a DSP on the sampled signal



Merge, Pass-through & Split Groups

MCR Advantages

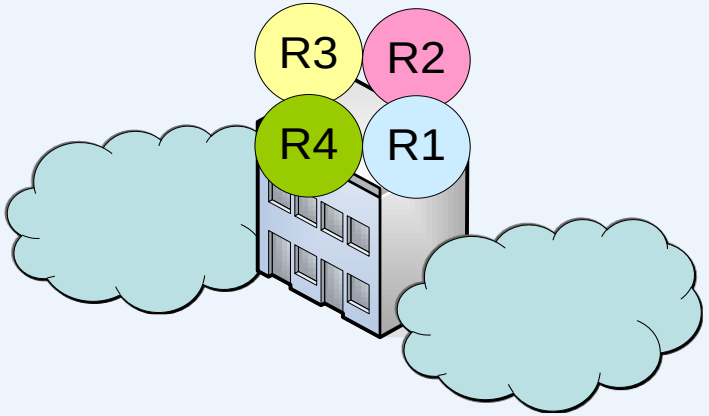


Merge, Pass-through & Split Groups

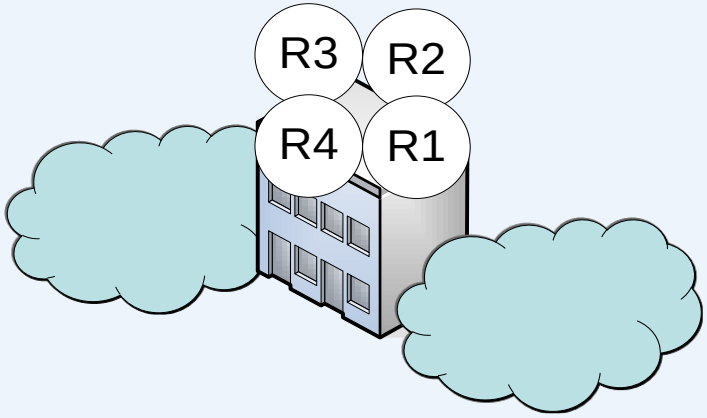
- Establishing communication for merging or passing-through groups with MCR
  - Faster & simpler algorithms with lower communication resource requirements
  - No reduction of the per node rate in a unified group (inter-cluster communications)
  - Better spectrum utilization
  - Easy switch from a contended channel

Routing/Relay Advantages with MCR

- 1-Ch. MANET:
  R_1 is a relay bottleneck



- MCR MANET:
  All the relevant nodes can RX and relay traffic to/from any channel



MCR Highlights

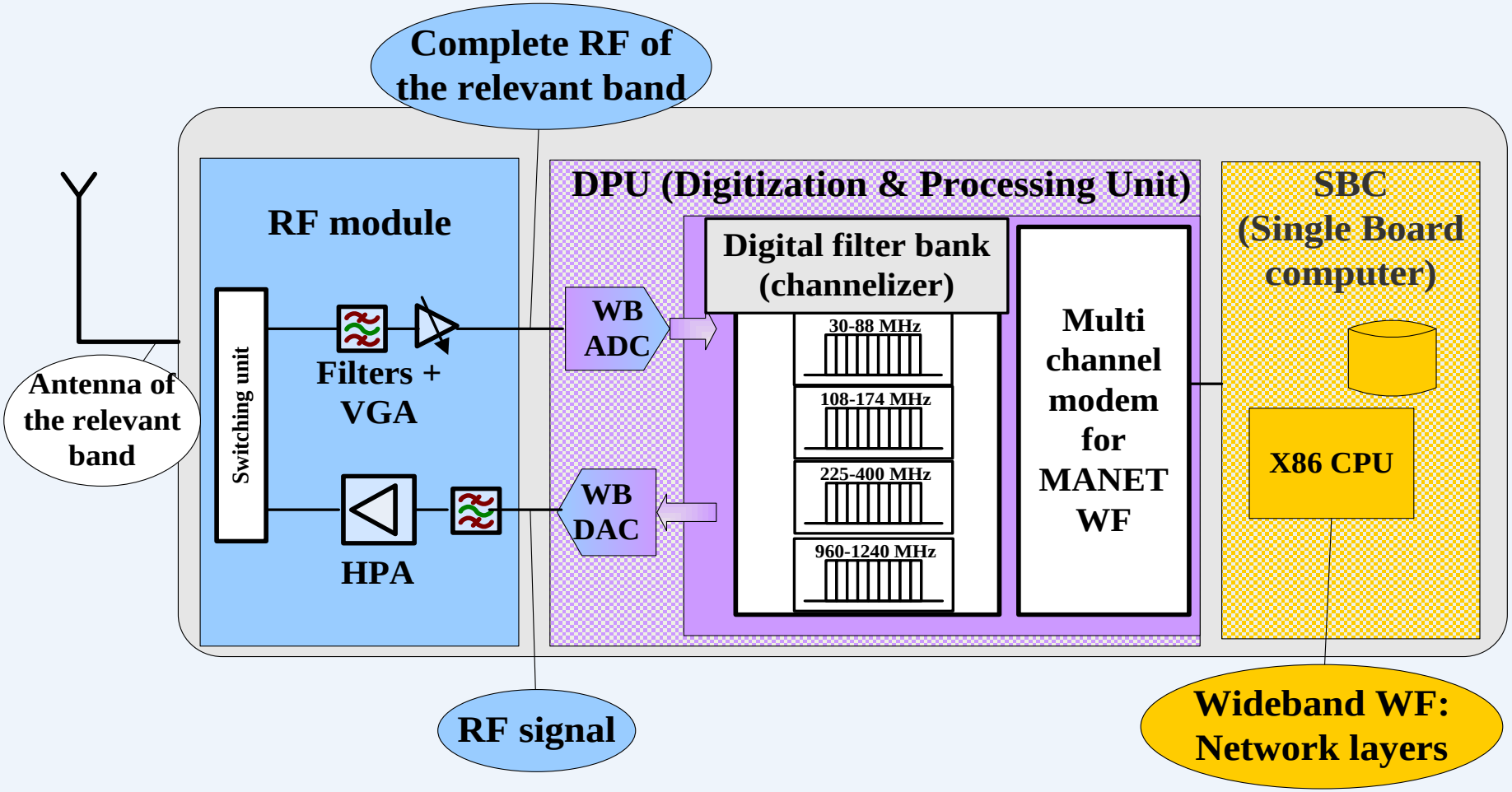
- Spectrum Utilization
  - Network can use all the channels all the time
- *RX throughput* is bounded by *channel throughout* **times** *the number of channels*
- Resource Management
  - Becoming at least 2D (time & channel)
- No Need For Receiver Frequency Hopping

MCR - Max Channels Number

- Half Duplex poses a question:
  - What is the optimal number of channels?
- A full mesh of 10 nodes with 10 channels
  - Simultaneous TX by all - nothing RXed
  - TX one by one - just as 1-channel TDMA
- Max throughput => N/2 channels
- Min propagation delay[1] => sqrt(N) [ch].

1 - S. Avadis, A. Lerner, & Z. Nutov, “MMM: multi-channel TDMA with MPR capabilities for MANETs,” Wireless Networks, Springer, DOI 10.1007/s11276-012-0468-6.

SDR Architecture



An “Ideal SDR”

- SDR Forum Definition
  - *“Radio in which some or all of the physical layer functions are software defined.”*
- Wikipedia Definition
  - *“The Ideal SDR receiver scheme would be to attach an ADC to an antenna…”*

Digitization & Processing Unit (DPU)

- DSP & modem implemented in firmware
  - Can be a part of a SCA framework
- Ultra Fast/UWB ADC (1.8 GSPS)
- Implemented with a Fast FPGA
- Cognitive Ready
  - 30 - 2,000 MHz; optionally up to 2,700 MHz
  - Instantaneous Spectrum Analyzer

Single Board Computer (SBC)

- Implements MAC & network functions
- Implements system control functions
- Can run user applications
- Uses a common x86 architecture
  - A convenient development platform
    - Running Linux, Eclipse, Matlab etc…
  - Common & HW acceleration libraries
    - Boost, IPP…

Network Highlights

- Network stack is inherently IP compliant
  - Supporting unicast, multicast and broadcast
- Networks are logical (as multicast groups)
  - Network ≠ Frequency channel
  - Frequency channel allocation is done by MAC
- No need to coordinate TX frequency
- Network control is just another application with an appropriate QoS

Medium Access Control (MAC)

- Schedules TX & RX according to priority and QoS requirements
  - Periodical Messages
  - Session based traffic
    - Voice (PTT & VoIP)
    - Video
  - Non-periodical traffic
- Uses distributed & adaptive algorithm
  - Time synchronization is assumed

Examples Of Supported QoS Types

- Delay
  - Real-time Voice, Video, Collision Warning
- Message rate
  - Situation Awareness, Collision Warning
- High reliability
  - File transfer

SDR Highlights: L2 or L3 ?

- L2 - the SDR functions as a bridge between Ethernet and the MANET
- L3 - the SDR functions as a router between MANET and the wired network
  - A software router can be run on the SBC
  - Can provide DNS and other services to the local network
  - Can be a MANET's gateway to a WAN

Rate Estimation

- RXed packet characteristics include
  - Received power, frequency & noise level
- Knowing the TX power => link attenuation
- Other's noise level => SNR of the receiver
- Knowing destination SNR allows choosing a proper TX rate (sub-waveform)
- The rate can be compared with the cost of routing to the same destination

Summary

- The MCR allows a breakthrough in terms of MANET performance
- The presented SDR architecture provides substantial new capabilities and flexibility
- The above is just a glimpse into the novel concepts, which revolutionize the way we think of MANETs and SDRs

Thank You!

Questions?

Please contact alexno@rafael.co.il

The BNET Multi-Channel Reception SDR Family

Breakthrough network Capacity, Delay, Scalability -Data, Video, Voice on the move

BNET- Airborne

Up to 3 Bands X 50 [W] TX

Manet +AM/FM+ UHF Satcom

10 Kg, ½ ATR (35X19X13 cm)

Tx =Rate: up to 10 Mb/s

Rx Rate: > 200 Mb/s !

BNET- Vehicular

Up to 2 bands X 50[W]

TX Manet + AM/FM

8 Kg, 30X20X10 cm

Tx =Rate: up to 10 Mb/s

Rx Rate: > 200 Mb/s

BNET- Hand Held

1 band 5 [W] TX

Manet or AM/FM

1.2 Kg (incl. battery)

Tx =Rate: up to 2 Mb/s

Rx Rate: > 20 Mb/s

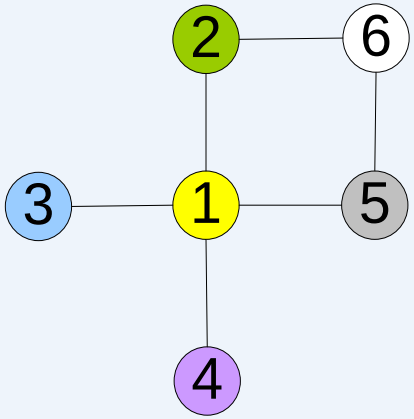
(A 4 Kg, 2 Bands, 20 W, larger battery Manpack will also be available)

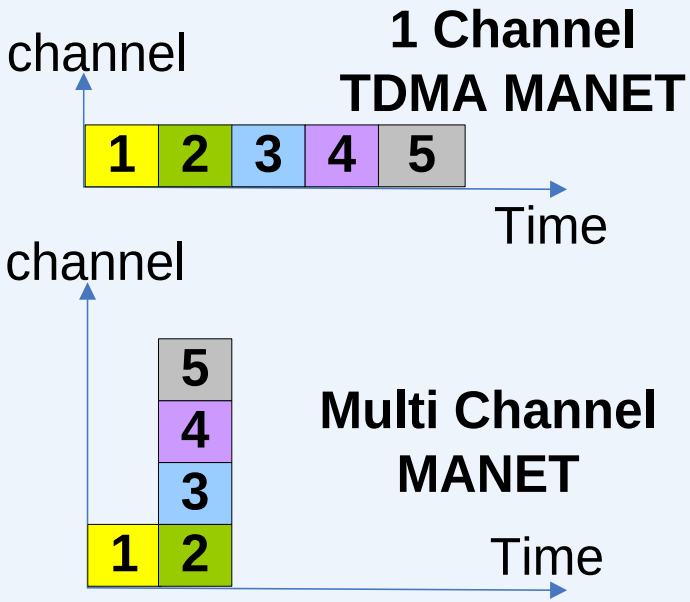
- Different Chasses & Cooling
- Different WF (OFDM vs. Single Carrier)
- Identical Modules

Backup Slides

Shorter Network Delay

- In the example below, MCR allows immediate RX of all the responses
- Lower delay is crucial for real-time applications
  - Voice
  - Video





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[2] L. Bao, "MALS: Multiple Access Scheduling Based on Latin Squares", In MILCOM 2004 - IEEE Military Communications Conference, no. 1, Oct 2004, pp. 426-426.

[3] L. Bao and J.J. Garcia-Luna-Aceves. "A New Approach to Channel Access Scheduling for Ad Hoc Networks". In Proc. ACM Seventh Annual International Conference on Mobile Computing and networking, Rome, Italy, Jul. 2001

[4] R. Rozovsky and P. R. Kumar. "SEEDEX: a MAC protocol for ad hoc networks". In Proc. of the 2nd ACM International Symposium on Mobile Ad Hoc Networking and Computing (MobiHoc) 2001, pages 67–75, Long Beach, CA, USA, Oct. 4-5 2001.

[5] M. Wermuth, Y. Wermuth, M. Weiss, S. Avadis, Y. Fuchs, "An Improved Mobile Ad-Hoc Network", Pending Patent application # IL216282, Dec 2011.

BNET MANET services and QoS levels

Service	Essence
PM (Periodical Messages) Example: SA (situation Awareness)	• Optimized for **periodical, delay-sensitive** data • **Broadcast, Multicast and Unicast** • **Adjustable reliability** using FEC packets
NPM (Non Periodical Messages) Example: Commands, Frozen pictures and files	• Optimized for **non-periodical, less delay sensitive** data • **Multicast and Unicast** • **Reliable + reception indication** using optimized TCP
Multimedia Video and Voice	• Optimized for multimedia: **video streaming, video on demand, voice over IP (VoIP)** • **Broadcast, Multicast and Unicast** • **Low jitter** service • **Reliability** using bandwidth reservation and FEC