Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [How To Increase Capacity Ten-fold in Radio Packet Data Networks]
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Re: [Wireless Next Generation Technology]

Abstract: [Improvement in the utilization of radio channels can be immensely improved a) with better use of channel time through by queuing contending packets, use of interference limited-radio system design, use of redundant and overlapping radio coverage for path diversity, improvement of access methods to make full use of advance knowledge of many knowable parameters and other details. This requires coordination of multiple access points and a central channel manager in a form architecturally different than ad hoc peer-to-peer networks. Configuration optimizes for the dominant traffic to be for internet access.]

Purpose: [Trial of whether these differences in initial assumptions for optimization criteria are of interest to IEEE 802.15 WNG attendees and members.]

How to Increase Capacity
Ten-fold
In Radio-Linked Packet Data Networks

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Introduction

This talk is about how to provide a better packet transport service than has been done by the most widely used IEEE 802 LANs suitable for radio transmission. Using methods to be shown, ***a gain of more than 10:1 in medium transport capacity for a given bandwidth and coverage area may be achieved*** relative to existing LAN/internet technology. This advantage can be taken as bandwidth or power in any combination.

The better service is in a network at the “edge” of the legacy TCP/IP network. The first users might be private systems who will benefit from predictable capacity and transit delay, from higher accuracy and coverage reliability and from much better physical layer security. This benefit will occur within the user’s system.

The Basis For Improvement

The stated gain of 10:1 is the combination of several different techniques in radio topology, radio modulation and coding, access protocol, traffic algorithms and a number of architectural details.

Intelligent infrastructure is an essential enabling requirement for much more secure and efficient packet date networks. It will be seen that while modulation is important, protocol and architecture are equally important.

Improvement Elements Description

- Interference-limited radio system design
- Path diversity derived from overlapping radio coverage
- Traffic model based on blocked transfers queued until cleared
- A dedicated narrow band access, status and control channel for each user
- Wideband allocated bandwidth for data packets or video connections
- Advance knowledge of status, privileges and location of all users
- Traffic statistics and equipment-performance recording.

This is not intended to describe the equipment that can provide the service, but to point out how much improvement is available from a better system concept.

Interference-limited System Design

Interference limited system design is necessary when an area is to be covered with a large number or access points, and it is desired to have intensive frequency re-use.

The intent is not to have an absence of interfering signals, but rather the desired path has enough level margin to over-ride the interference.

Critical factor: ***Capacity per unit area is a strong function of the required like-signal protection ratio.***

Radio Coverage Layout

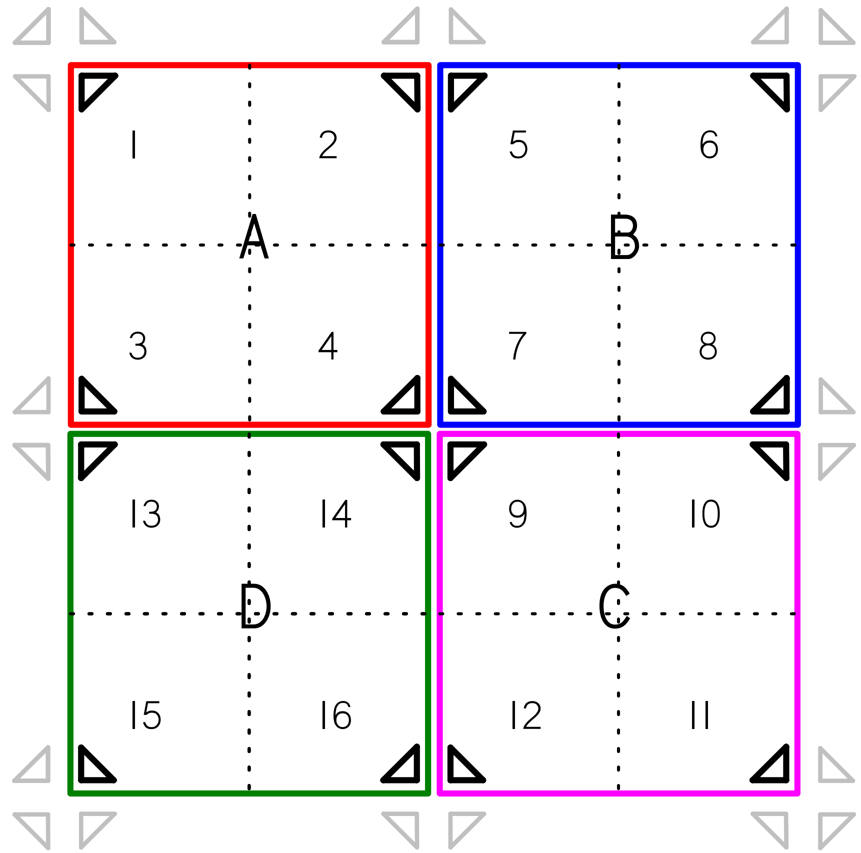
There 16 coverage's in 4 areas label A to D.

Areas A1, B5, C9 and D13 might use the same radio channel

Channels can be derived by frequency or code division multiplexing.

Each antenna has a 90 degree beam-width.

Coverage's overlap

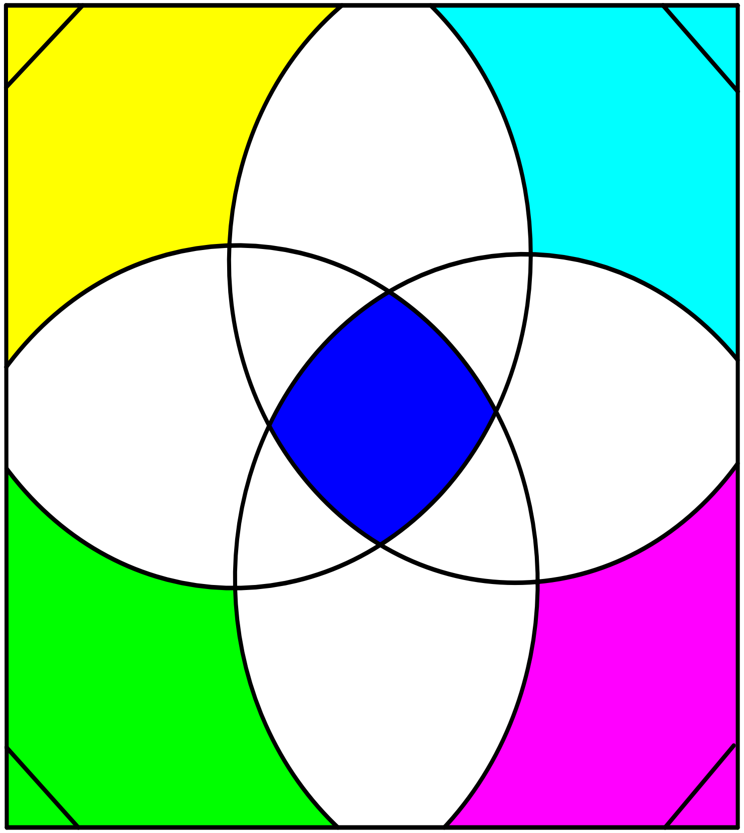


Path Diversity from Overlapping Coverage-1

The Access-Points are at the corners of the square.

Each antenna is pointed at the center of the square and field strength is somewhat less 45 degrees off center.

There is overlapping coverage from four access points in the center, and from just one access point in the colored corners. There is double coverage in the white areas.



Path Diversity from Overlapping Coverage-2

Stations will not always have a usable path to the nearest access point, however there may be a satisfactory path to a more distant access point.

All access points will inevitably have excess range if they cover nearly all of the necessary range.

Path diversity is likely to be more effective in recovering from fade nulls in the primary path than high-redundancy, forward error correction.

The ability to use alternate paths best provided with infrastructure that collects all status information at a common point. The path selection function is better performed by nodal switches specifically designed to use the collected information in the best way.

Modulation for Bounded Systems

Several considerations limit choices for radio modulation:

The simplest modulations require the smallest signal-to-interference ratio. This is good for intensive frequency reuse.

Wideband modulation is best for minimizing average power per bit required—but gain diminishes to a limit for wider spreads.

Wideband modulation increases resistance to narrow band or cancellation type fades--the wider the better. More transmitter power is very weak in reducing the effect of these fades.

Under a regulatory power density limit, a wideband or a low duty cycle with high peak-average modulation may be used.

Good choices have many but rarely all of the desirable traits.

Traffic Model: Blocked Transfers Queued Until Carried

The classic Erlang C blocking formula assumes that all submitted traffic is carried (up to the capacity limit) however the traffic must be queued whenever no path is available at the time it is offered. Some fraction of the offered traffic will be delayed. That delay is specified as a multiple of the average duration of a packet (connection). At a ***loading of 90%,*** it will be rare for this delay to exceed 6 durations (An average duration might be 1,000 octets which at 10 Mbps would be 800 µseconds).

The implementation of this algorithm, requires the allocation manager to have advance knowledge of what traffic must be scheduled.

Reserved Low-capacity Control Channels

To enable the implementation of this algorithm, there must be a queuing mechanism for delayed packets. That queuing mechanism requires knowledge of pending traffic before transmission capacity is committed.

Using time sharing to provide a reserved capacity low-rate channel for each associated user station, service requests can be made when the traffic channel is at saturated load. The frequency of service request opportunities may be made adaptive increasing for currently active stations. The reserved channels will divert about 4-8% of total channel capacity

It is essential that there be a back indication that the system cannot pass the requested traffic.

Wide-bandwidth Allocated Data Packets

The remaining bandwidth is used for asynchronous packet transfer as scheduled by a central manager.

This channel may also be used for streaming video if packetized.

The packets on this sub-channel are ***larger than 48 octets***. The shorter messages can be passed on the non-blocking facility.

At peak loads, the packets are passed consecutively with minimal gaps between packets.

Benefit from Protocol with Queuing

The gain of this mode is increased peak load carrying utilization from 30 to 90% or 3X.

This gain need not discounted for diversion of bandwidth for the non-blocking service, since most of this traffic would be carried any way.

The net protocol gain is then about 3.0X.

Advance Knowledge of Status and Location-1

The presumption should be made that only authorized users (as determined by the network operator) will be able to associate with the network. The means for enforcing this policy must be built into the system design.

It is important to filter un-permissible traffic at the point of entry and not at each individual user’s terminal. The right to originate multi-cast messages in volume should be defined in a user’s profile.

Advance Knowledge of Status and Location-2

There is important user information that can be known before a packet is submitted for transfer. Legacy packet networks are obliged to discover some of this information for each packet individually.

Legacy system use broadcast messages (counted as payload not overhead) to discover many of these facts.

The location, best path and usable alternate paths are important facts that should be known before a service request.

Advance Knowledge of Status and Location-3

A very important stored property should be the access route to each user and a status of associated stations. Determining this by sending a packet without knowledge that destination is present and available is a cause of wasted capacity.

The gain from advance knowledge of route and status is estimated at 1.5X (understatement).

Much of the gain in this function is as much in waste load avoidance rather than improvement of carrying capability.

Statistics and Performance Recording

It is very valuable to record traffic statistics particularly including failed access, delays, retries and transfer rates. This capability must be built-in from the beginning of the design. The measuring points may be all over the system, but the collection and compilation must be central.

Without an objective way to measure system performance that carefully observes failures of all types, it is not possible to evolve into high reliability.

An important step in gaining high success rates on packet transfers, is by reducing the need for repeat transmissions.

Totaling the Advantage

The present estimate is the product of three described factors:

Interference limited system design:	3X
Queuing access protocol:	3X
Use of known information:	1.5X
Total gain:	**13.5X**

For simplicity, this is rounded off to 10. This gain may be taken in channel bandwidth or transmit power or in any other way expressed in terms of power.

Applying This Technology To Future Office Building Networks

The service provided is packet relay in a radio bandwidth of 4, 8 or 16 Mbps at 5.2 GHz. In a 100 MHz bandwidth, this corresponds to 16, 8 or 4 frequency division channels.

In large office buildings with cubicles or the floor of a convention center, four radio access points at the corners of a rectangular floor space of up to 300 x 300 feet can serve several hundred users at the 16 Mbps rate..

The service provided will resemble a DSL line for each user provided by radio (or Cat-5e cable). The service on that line will be LAN, Internet shared channels and voice telephone on reserved space channels.

Quality of Service Attributes

- Reliable first-try signaling using path diversity, which avoids FEC and dependence on higher layer send-again.
- Underlying low-rate reserved paths allows entry of service request and all's well messages even though channel is loaded to capacity at 90%.
- Packet traffic pending channel availability is held at a send-end FIFO and released in order-of arrival when channel is available. There is no contention loss in the system, but there is delay of the order of a few seconds.
- Low side lobe energy enables closer spacing of frequency division channels.

Maybe The Time Has Come

There can be a design for a LAN radio system

that is <u>optimized</u> for

the security, convenience and

economy of operation for the user.

What Next

Individuals that invest in development, are frequently motivated by the perception of an unmet market need.

Speculative technology development may reach a demonstration model, but must attract larger investments for further progress to commercialization.

The described technology can make a meaningful difference in the services and capacity available to major users of communication.

Further development collaboration would be welcome.