IEEE P802.15 Working Group for Wireless Personal Area Networks™

SCORT - An Alternative to the Bluetooth SCO Link for Voice Operation in an Interference Environment

Bluetooth SCO Link

- The Bluetooth SCO Link is a periodic transmission
  - HV3: 2 out of 6 slots used (No FEC)
  - HV2: 2 out of 4 slots used (2/3-rate FEC)
  - HV1: 2 out of 2 slots used (1/3-rate FEC)
- The SCO packets do not include a CRC and retransmission is not included.

Bluetooth SCO Link

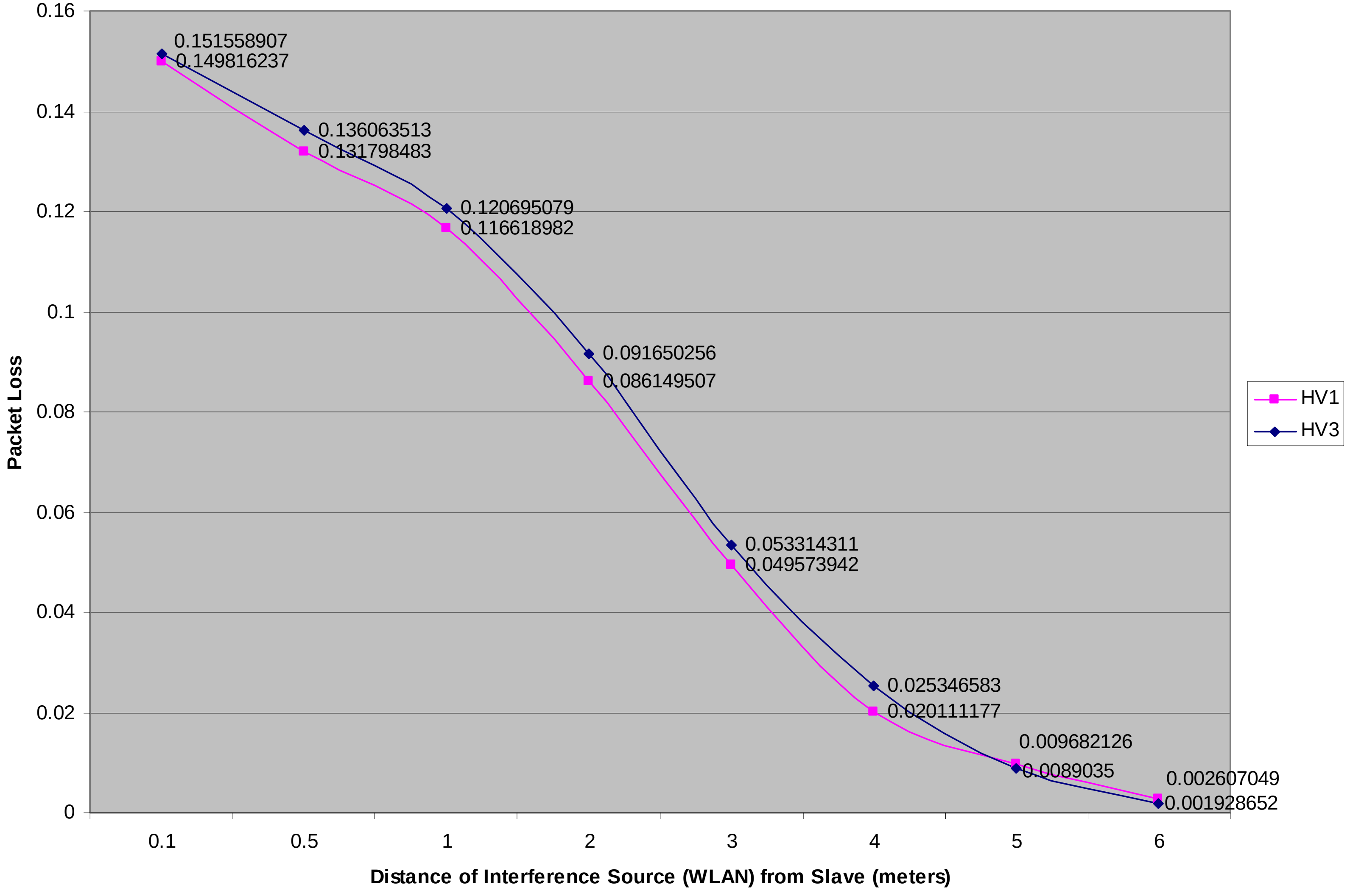
- The SCO Link, as an interferer, represents periodic interference with a short period.
- If the Bluetooth power level at the 802.11 receiver is too high, then this periodic interferer is potentially a worse interferer than an ACL Link.

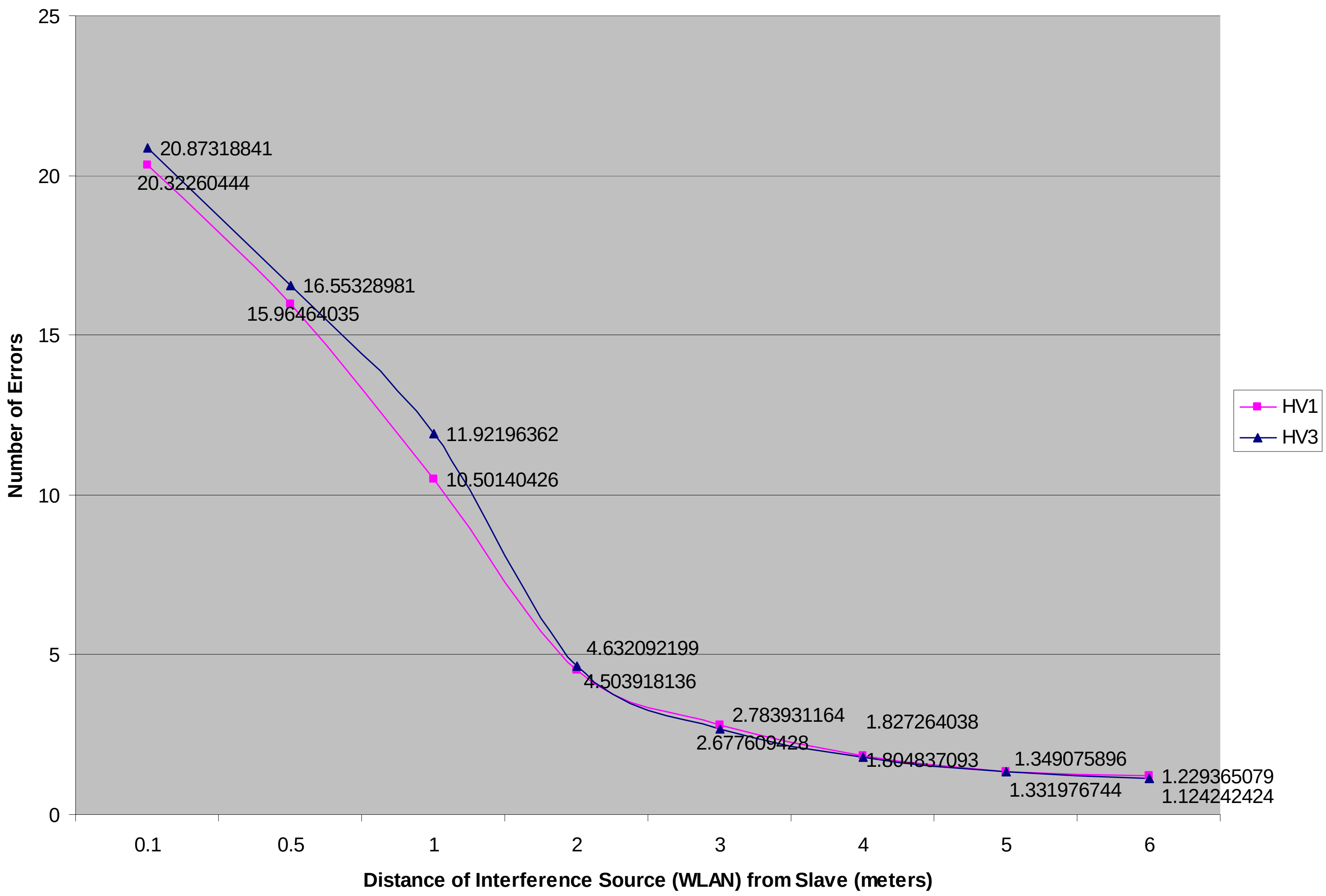
Bluetooth SCO Link

- The SCO Link is more susceptible to 802.11 interference than an ACL Link
  - Under interference it is more likely to cause full packet errors, not just a few bit errors
  - The FEC does very little to mitigate the effect of interference.
  - The SCO link does not support Packet Redundancy, which is what is needed in an interference environment

SCO Link Simulation

- Nada Golmie IEEE 802.15-01/388r0
- Simulation of Bluetooth SCO Link in an 802.11b environment
- SCO Packet Loss Rate
- Residual payload bit error rate


Packet Loss
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.151558907
0.149816237
0.136063513
0.131798483
0.120695079
0.116618982
0.091650256
0.086149507
0.053314311
0.049573942
0.025346583
0.020111177
0.009682126
0.0089035
0.002607049
0.001928652
0.1
0.5
1
2
3
4
5
6
Distance of Interference Source (WLAN) from Slave (meters)
HV1
HV3


25
20
15
10
5
0
Number of Errors
20.87318841
20.32260444
16.55328981
15.96464035
11.92196362
10.50140426
4.632092199
4.503918136
2.783931164
2.677609428
1.827264038
1.804837093
1.349075896
1.331976744
1.229365079
1.124242424
HV1
HV3
0.1
0.5
1
2
3
4
5
6
Distance of Interference Source (WLAN) from Slave (meters)

Bluetooth SCO Link

- The SCO Link is weak in an interference environment.
- The FEC is not that beneficial in an interference environment. This is because the bit errors in a packet are not independent.
- **Recommendation: Replace bit-level redundancy with packet-level redundancy.**

New Link Type for Voice

- Keep the Link Connection-Orientated
- Keep periodic transmission
- Eliminate the FEC option
- Add a CRC
- Add packet redundancy

SCORT Link

- Synchronous Connection-Oriented with Repeated Transmission (SCORT) Link

Design of New Packet

- The maximum payload size in Bluetooth is 30 bytes.
- If we add two bytes for a CRC then we can allocate at most 28 bytes for voice data.
- Need to meet the 64,000 bits/second throughput requirement.

Throughput Calculation

- Throughput formula,

$$\left(\frac{\text{bytes}}{\text{packet}}\right)\left(\frac{\text{packets}}{\text{second}}\right) = \left(\frac{\text{bytes}}{\text{second}}\right)$$

- Required Throughput for a one-way link,

$$\left(\frac{\text{bytes}}{\text{second}}\right) = 8000$$

Throughput Calculation

- Packet rate can be written as,

$$\left(\frac{\text{packets}}{\text{second}}\right) = \text{Utilization}\,(1600)$$

- Utilization (fraction of total packets used) is given by,

$$\text{Utilization} = \frac{5}{\left(\frac{\text{bytes}}{\text{packet}}\right)}$$

Throughput Calculation

(bytes/packet)	Utilization	Comments
30	1/6	SCO HV3 Packet
28	5/28	Maximum number of bytes per packet
25	1/5	Ratio of smaller integers

Throughput Calculation

- Select 25 bytes/packet for simplicity.
- We want to repeat each packet twice so we need to double the utilization
- We also want to have a two-way link, so we need to double the utilization again.
- Total Utilization for this two-way link is (4/5).

SCORT Packet

- Put 25 bytes of voice data in payload
- Add 2 byte payload CRC
- Total payload is 27 bytes < 30 bytes
- Transmit each packet twice.
- If first packet has correct CRC use it.
- If first packet is bad and second packet is good, use second packet.
- If both packets are bad use a benign filler packet.

SCORT Packet

- Use 8 out of every 10 packets
  - 80% Utilization of piconet capacity
- Leave 2 packet for ACL traffic
  - 20% capacity remaining for data

Master Packet 1	**Slave Packet 1**	**Master Packet 1**	**Slave Packet 1**	**Master Packet 2**	**Slave Packet 2**	**Master Packet 2**	**Slave Packet 2**	**ACL Data**	**ACL Data**

Packet Loss Rate Calculation

- Assume the uncorrected packet loss rate is *p*
- The corrected packet loss rate is p^2

Uncorrected Packet Loss Rate (p)	Corrected Packet Loss Rate (p^2)
20%	4%
10%	1%
5%	0.25%

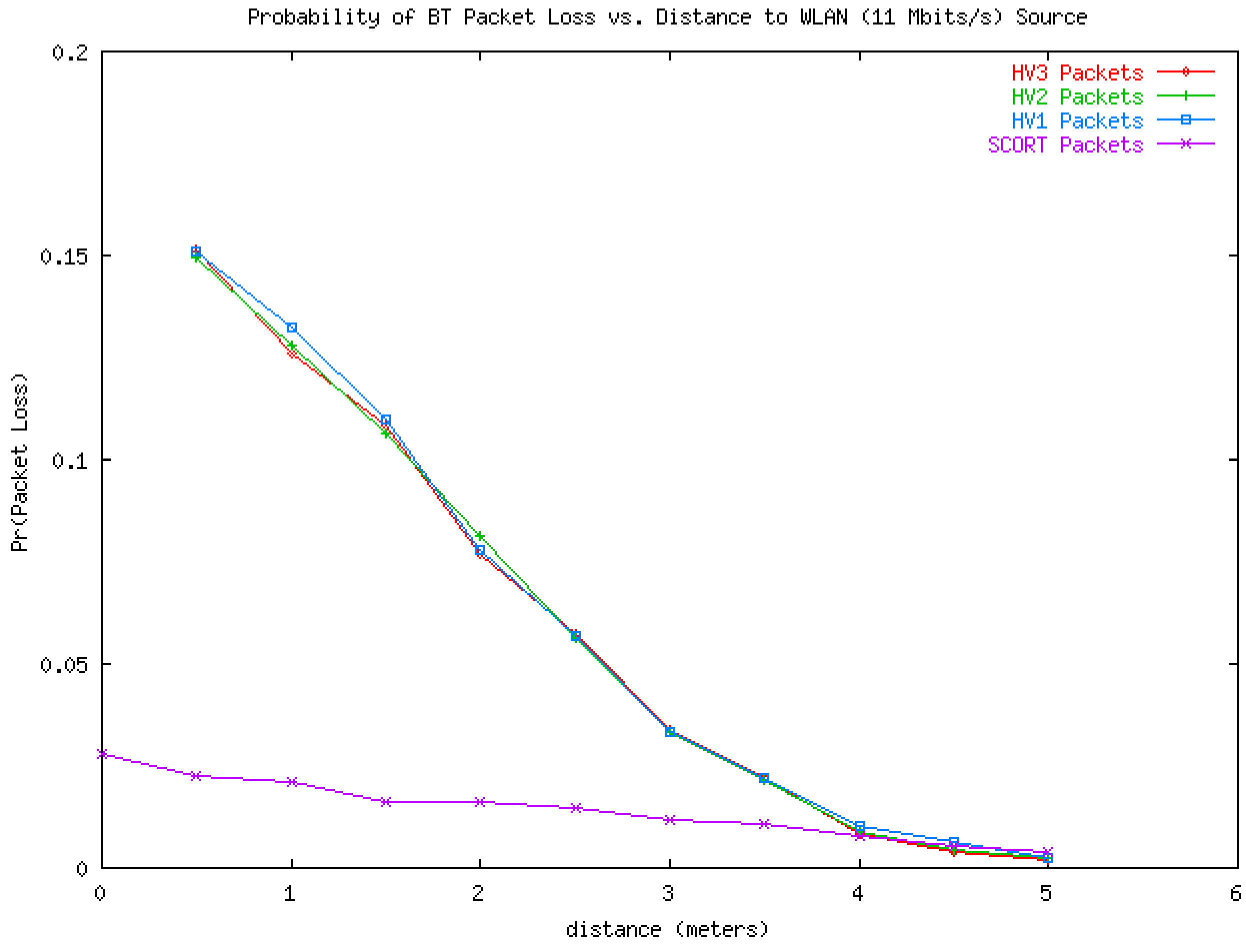
New Simulation

- At my request Nada Golmie simulated the SCORT link, and the original SCO links, in an IEEE 802.11b interference environment.
- Plotted
  - Packet Loss Rate
  - Residual bit errors in SCO links

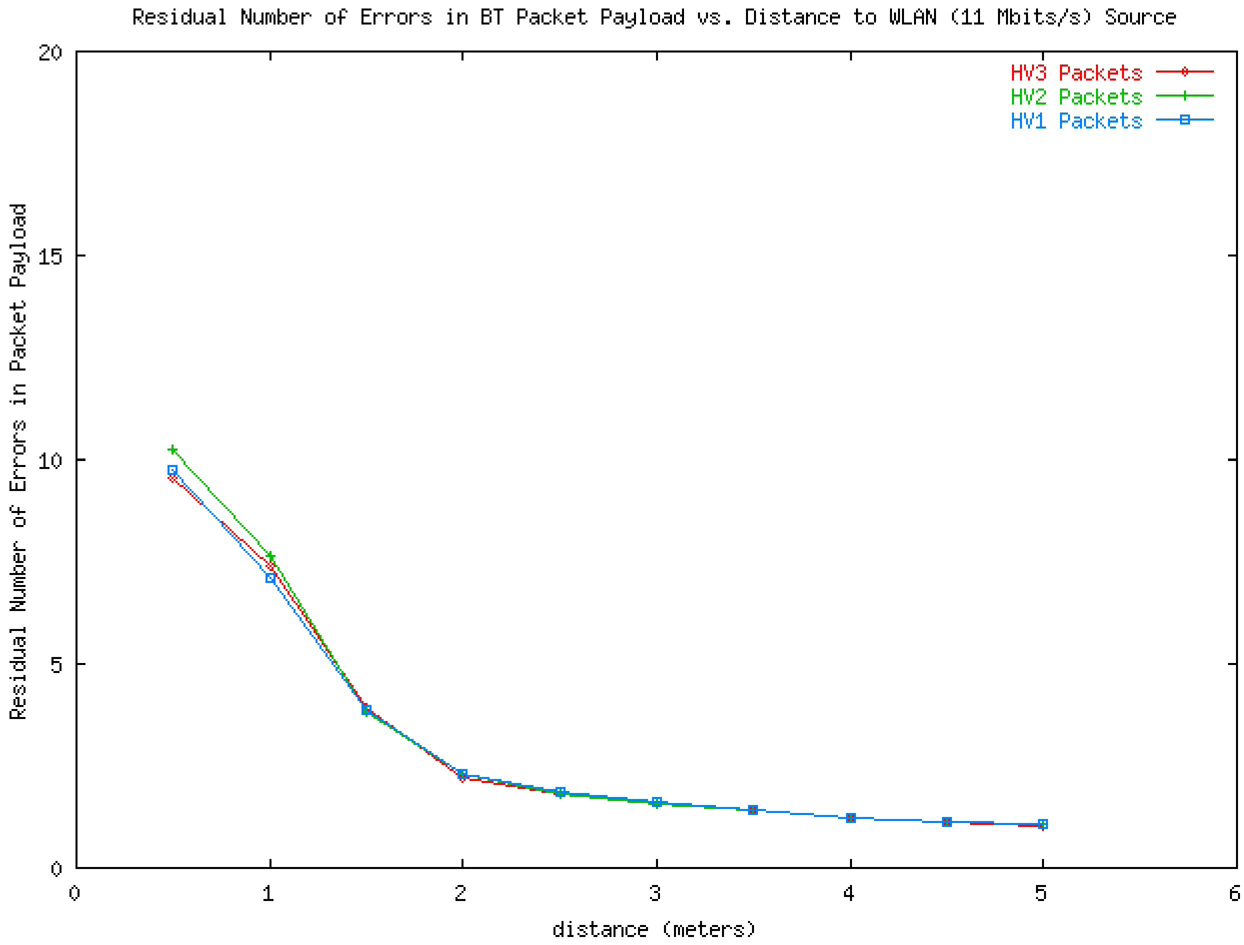
New Simulation

- Packet Loss Definition:
- For SCO Link
  - Bad Synch word or Bad Header
- For SCORT Link
  - Bad Synch word or Bad Header or Bad Payload

New Simulation - Packet Loss Rate



New Simulation - Residual Bit Errors



Summary

- SCO Link with FEC
  - Uses redundant *bits* within a packet, whose probability of error are **not** independent
- SCORT Link
  - Uses redundant *packets*, whose probability of error are independent.

Summary

- SCORT Link
  - Uses 80% of the piconet capacity, which is less than the HV1 Link, which uses 100% of the piconet capacity
  - Has much better performance than HV1 Link in an interference environment.
- If packet is bad, then a benign filler packet can be substituted for bad packet, resulting in better audio fidelity.