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# User Perceived Bluetooth Interoperability

Daniel Deavours  
James Dawkins  
et al.



# Outline

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- What is Bluetooth?
- What am I doing with Bluetooth
- Background Information
- Lots of Results
- Conclusions



# What is Bluetooth

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Bluetooth is a short range wireless technology intended to replace wires from electronic gizmo's.

- Big 4
  - Cell Phones
  - Headsets
  - PDAs
  - PCs
- Etcetera
  - Printers
  - Keyboards, mice
  - GPS
  - MP3 players
  - Game devices

# Bluetooth Factoids

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- Works in 2.4 MHz “ISM” band
  - 2.402 – 2.480
  - Shared by: 802.11b, 802.11g, cordless phones, microwaves, baby monitors, etc.
- A “good citizen” in the 2.4 band
  - Spread spectrum, frequency hopping
  - 79 channels, pseudo-randomly chosen
  - 625 micro-seconds / channel – fast hopping
  - 1.2 spec allows for adaptive frequency hopping, discarding up to 23 channels
- Short range = low power
  - Class 3 (1 mW) and Class 2 (2.5 mW) are most common, but Class 1 (100 mW) are also available. 802.11 often runs at 20-100 mW.



# More Factoids

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- **Bandwidth**
  - 1 mbps, compare with 11 mbps and 54 mbps with 802.11 standards
  - Robust and simple (802.11 often works slower than top speed)
  - A 2 mbps and higher are being considered
  - Supports asynchronous and synchronous at link level
  - Security designed, not an afterthought
- **Protocols and Profiles**
  - Bluetooth has an extensive list of protocols and profiles
  - Detailed, robust link and network layer protocols
  - Few transport layer protocols (SPP)
  - Numerous (too numerous) session / application layer profiles
- Well defined “profiles” of communication simplify the design process and enhance interoperability among disparate devices

# Perspectives

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- The (potential) competition
  - Wireless USB
    - Targeting 400+ mbps
    - Well established
  - UWB = Ultra Wide Band
    - Very high bandwidths possible, 100 mbps+
    - Very robust; multi-paths mitigate
    - Stuck in standards process
    - Potential regulatory problems
  - 802.11
    - Not really a competition
    - 802.11 replaces Ethernet cable
    - Bluetooth replaces the rest



# The Project

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In 3Q 2002, the Bluetooth SIG approached us to explore some issues.

- There was widespread perception that Bluetooth “doesn’t work” and that the technology “wasn’t ready.”
- Devices that were supposed to work together didn’t. Bluetooth was getting bad press.
- Nobody took a diligent look at the issue, so there was no basis to say whether Bluetooth worked.
- Does it?



# The Devices

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- 66 devices were provided by the SIG
  - 7 Handhelds
  - 12 Mobile phones
  - 21 Headsets
  - 12 PCs (2 integrated, 10 adapters)
  - 4 HID
  - 4 Printer adapter
  - 3 Access points
  - 2 GPS
  - 1 Imager
- New devices being added regularly (now nearly 80)
- *Do these devices interoperate like they should?*



## Definitions of *interoperability*

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- IEEE/ISO
  - The ability of two or more systems or components to exchange information and use the information that has been exchanged
- Bluetooth
  - The ability for an end-user to make two or more devices to perform their desired Bluetooth functions, independent of the producers of the device
- AAP
  - The condition achieved when two or more technical systems exchange information directly in a way that is satisfactory to the users of the systems

# Causes of Interoperability Failures/Problems

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- **Device not designed to work as expected**
  - E.g., Mobile phone that does not support headsets
  - Dongle with HID doesn't support exchanging an image
  - Misleading or insufficient documentation
- **Incompatible profiles**
  - E.g., Mobile phone implements Hands Free Profile, headset implements Headset Profile
  - E.g., Object Push vs. File Exchange
  - E.g., SPP vs. BPP vs. HCRP
  - Profile proliferation without deprecation will ensure problems
- **Bluetooth failures**
  - E.g., Device has user interface supporting transferring a picture, but freezes while sending the file.
  - Results are from black box testing so the root of all failures is not always discernable.
- **Usability issues**
  - Networking from PDA using PC
  - FAX from PC using mobile phone
- **Other problems**
  - Incompatible file and data formats



## Example Headset Packaging and Labeling



- “Hands-Free Headset” is a common term used with headsets.
- With Bluetooth, “*Hands Free*” and “*Headset*” are names of profiles.
- This device supports *Hands Free* profile, not *Headset* profile

# List of Test Cases

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1. Business card exchange
2. Transfer an address book entry
3. Transfer a calendar entry
4. Transfer a picture
5. Dial-up networking
6. Transfer of recorded audio
7. Fax test
8. Synchronize data
9. Audio Headset Test Group
  - 9.1. Call from Mobile Phone
  - 9.2. Call from Headset
  - 9.3. Receive with Mobile Phone
  - 9.4. Receive with Headset
  - 9.5. Transfer between Mobile Phone and Headset
10. LAN access to the internet
11. Play music/audio
12. File sharing
  - More are being added

# When Should a Test Case be Applied?

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- *If users expect it*
- Users have default expectations
  - E.g., mobile phones and headsets will work together
  - E.g., PCs can exchange pictures
  - E.g., Handheld can sync with PC, etc.
- Packaging and documentation can add and subtract
  - A “hands-free” headset
  - Mobile phones sync with other mobile phones
- Open questions
  - Who are users?
  - What do they expect?
  - To date, we’ve used our best judgment
- New work starting to address this question
  - Surveys, focus groups addressing what tasks users expect particular device pairs with Bluetooth to accomplish.
  - Usability testing.



# Collected Data

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- The following data was collected for each test case
  - Success or failure
    - Failures further broken down into different types
  - Transient errors observed
    - E.g., device not found, dropped connection, pairing error
  - Time (not rigorous)
    - Only includes actual testing time for a particular test case
    - Does not include time to perform the hard reset on both devices, time for documentation, or any other overhead.
  - Subjective scale (for usability, not rigorous)
  - For some failure's the protocol analyzer was used to collect the wireless conversations between the device pair.

# What is a Failure?

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- A *failure* is declared when we can not achieve the purpose of the test case with reasonable effort.
  - Like proving a negative; it's impractical
  - Relies on some cleverness of the tester; subjective and biased
- Rigorous failure declaration process
  1. Repeat the test step that failed.
  2. Repeat the test case containing that test step after resetting both the devices.
  3. Ensure proper battery charge on both devices and repeat the test case.
  4. Refer to the user manual to check whether the operation is carried out as instructed.
  5. Refer to latest online resource to find any updates to manual and additional support.
  6. Repeat test case with a different test operator.
  7. Bring the devices to a different environment, location and orientation and repeat the test case.
  8. Be creative and try some intuitive way to achieve the test purpose.
  9. Contact manufacturer technical support department.



# Types of Failures

| Abbreviations | Failure Descriptions   |
|---------------|--|
| UC            | “Unable to Connect...” Permanent Error                               |
| MBC           | “Max number of Bluetooth Connection...” Permanent Error              |
| InB           | “Internal Bluetooth...” Permanent Error                              |
| PNS           | “Profile not Supported...” Permanent Error                           |
| UDB           | “Unable to detect device during Bluetooth search...” Permanent Error |
| PE            | Pairing Error, “Unable to Pair...” Permanent                         |
| USF           | Device pair does not support feature under test                      |
| t&d           | Transferred calendar times and dates are incorrect                   |
| DL            | Data lost while transferring   |
| FS            | “Failed sending...” Permanent Error                                  |
| UFF           | Unsupported file format  |
| PNI           | Pairing cannot be initiated from device                              |
| UIT           | Unable to initiate Task  |
| NPr           | Device shows sending, but no progress made                           |
| NCP           | Device tries to connect with no progress                             |
| FnR           | “_____ found but not respond”  |
| nCC           | Receiving device cannot save calendar type                           |
| InD           | “Invalid data included”  |
| nCM           | Initiating device shuts down when camera option selected             |

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## Select Detailed Data

- Handheld – Mobile Phone: Transfer Picture
- Handheld – Handheld: Transfer Calendar Entry
- Mobile Phone – Mobile Phone: Transfer Recorded Audio



# Handheld – Mobile Phone: Transfer Picture

|                 |       | HH1 | HH2 | HH3 | HH4 | HH5 | MP1 | MP2 | MP3 | MP4 | MP5 | MP6 | MP7 | MP8 |   |
|-----------------|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|
| Potential Pairs | 104   | HH1 |     |     |     | 0   | 0   | 0   | 0   | 0   | x   | 0   | 0   | x   |   |
|                 |       | HH2 |     |     |     | USF | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   |   |
| Tested Pairs    | 73    | HH3 |     |     |     | x   | x   | x   | x   | x   | x   | x   | x   | x   |   |
|                 |       | HH4 |     |     |     | USF | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   |   |
| Passed          | 68    | HH5 | 0   | 0   | x   | 0   | x   | x   | 0   | FS  | 0   | 0   | FS  | 0   | 0 |
| Failed          | 5     | MP1 | 0   | 0   | x   | 0   | x   | x   | 0   | 0   | 0   | 0   | 0   | x   | x |
|                 |       | MP2 | 0   | 0   | x   | 0   | 0   | 0   |     |     |     |     |     |     |   |
| Pass Rate       | 93.2% | MP3 | 0   | 0   | x   | 0   | 0   | 0   |     |     |     |     |     |     |   |
|                 |       | MP4 | 0   | 0   | x   | 0   | 0   | 0   |     |     |     |     |     |     |   |
| Completion Rate | 70.2% | MP5 | x   | 0   | x   | 0   | x   | 0   |     |     |     |     |     |     |   |
|                 |       | MP6 | 0   | 0   | x   | 0   | 0   | 0   |     |     |     |     |     |     |   |
|                 |       | MP7 | UC  | 0   | x   | 0   | 0   | x   |     |     |     |     |     |     |   |
|                 |       | MP8 | x   | 0   | x   | 0   | 0   | x   |     |     |     |     |     |     |   |

- Blue = Untested; Red = Fail; Aqua = Pass
- Note: HH5 and MP1 are dual HH/MP devices
- High pass rate of 93.2%
- 2 of 5 failures due to HH2, and HH4 not being able to send a file to HH5
- HH5 to MP3 and MP6 would receive a “Failed Sending” permanent error
- MP7 -> HH1: Unable to Connect permanent error

# Handheld – Handheld: Transfer Calendar Entry

Potential 36  
 Tested 22  
 Passed 7  
 Failed 15  
 Pass Rate 31.82  
 Completion Rate 61.11%

|     | HH1 | HH2 | HH3 | HH4 | HH5 | MP1 |
|-----|-----|-----|-----|-----|-----|-----|
| HH1 | x   | USF | x   | UFF | UDB | UFF |
| HH2 | UFF | x   | t&d | 0   | t&d | t&d |
| HH3 | x   | 0   | x   | FS  | x   | x   |
| HH4 | FS  | 0   | t&d | x   | t&d | t&d |
| HH5 | PNI | 0   | x   | 0   | x   | x   |
| MP1 | UDB | 0   | x   | 0   | x   | x   |

- Low Pass rate ~32%
- 6 out of 15 failures due to incorrect time/date (t&d) when transferred
- 3 out of 15 failures due to unsupported file format (UFF).
- Format issues account for 9 out of the 15 failures (60%)
- Note: asymmetry in the data

# Summary/Implications

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- **Summary**

- Low pass rate for this test case, ~32%
- 6 out of the 15 failures due to incorrect time/date when calendar entry transferred.
- 3 out of the 15 failures due to incompatible file formats not recognized by other device; all three have to do with HH1.
- Combined file format issues account for 60% of all failures

- **Implications**

- By enforcing or adapting a standard calendar form when sending calendar entries 6 of the 15 failures could be corrected raising the pass rate to 13 of 22, or a 60% pass rate.
- Also if all handheld devices supported the same calendar file format then 3 out the 15 failures could be corrected further raising the pass rate to 16 of 22, or a 73% pass rate.

# Mobile Phone – Mobile Phone: Transfer Recorded Audio

|                 |       | HH5 | MP1 | MP2 | MP3 | MP4 | MP5 | MP6 | MP7 | MP8 |
|-----------------|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Potential Pairs | 81    | HH5 | x   | x   | UFF | 0   | 0   | 0   | 0   | 0   |
|                 |       | MP1 | x   | x   | UFF | FS  | 0   | 0   | FS  | x   |
| Tested Pairs    | 66    | MP2 | UFF | UFF | x   | FS  | UFF | UFF | FS  | UFF |
| Passed          | 48    | MP3 | UFF | 0   | 0   | x   | 0   | 0   | 0   | 0   |
| Failed          | 18    | MP4 | UFF | 0   | 0   | 0   | x   | 0   | 0   | 0   |
| Pass Rate       | 72.7% | MP5 | UFF | 0   | 0   | 0   | 0   | x   | 0   | 0   |
|                 |       | MP6 | UFF | 0   | 0   | 0   | 0   | 0   | x   | 0   |
| Completion Rate | 81.5% | MP7 | UFF | x   | 0   | 0   | 0   | 0   | 0   | x   |
|                 |       | MP8 | UFF | x   | 0   | 0   | 0   | 0   | 0   | 0   |

- 14 of 18 failures are due to incompatible file formats
- 4 of 18 due to “Failed sending” permanent errors
- Note asymmetry

# Summary/Implications

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- **Summary**

- Pass rate of 72.7% (48 of 66); indicates a moderate level of interoperability for this device type pair and test case.
- 6 of 18 failures came from mobile phones not being able to recognize recorded audio file sent from MP2
- 7 of 18 failures came from mobile phones not being able to recognize the `.wav` format used by HH5.
- 4 of the 18 failures due to “Failed Sending,” permanent error; this signifies that the operation was able to be initiated, but the audio file was never finished sending and was never received.
  - Possible low-level Bluetooth problems.

- **Implications**

- 14 of 18 failures could be corrected if both mobile phones and mobile phone enabled handholds adopted the same format for recorded audio files, or had the ability to recognize both `.amr` and `.wav` formats.
- This would raise the pass rate to 93.9% (62 of 66).

# Handheld – Handheld Aggregate: Failure Rates

|     | HH1 | HH2 | HH3 | HH4 | HH5 | MP1 |
|-----|-----|-----|-----|-----|-----|-----|
| HH1 |     | 40% |     | 40% | 57% | 71% |
| HH2 | 20% |     | 80% | 20% | 80% | 43% |
| HH3 |     | 40% |     | 60% |     |     |
| HH4 | 40% | 0%  | 80% |     | 80% | 43% |
| HH5 | 50% | 20% |     | 20% |     |     |
| MP1 | 50% | 33% |     | 33% |     |     |

|                 |     |                 |       |
|-----------------|-----|-----------------|-------|
| Potential Pairs | 36  | Passed TC       | 66    |
| Tested Pairs    | 22  | Failed TC       | 56    |
| Potential TC    | 248 | Pass Rate       | 54.1% |
| Tested TC       | 122 | Note: asymmetry |       |

# Handheld – Handheld Aggregate: Summary

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- Summary

- Overall Pass rate of 66 of 122 test cases, or 54%
- Of 47 of 56 failures could be eliminated:
  - 12 if all six handhelds could initiate a business card exchange
  - 8 if all devices had software supporting a business card exchange
  - 8 if HH2 and HH4 implemented a user interface to send files similar to other handhelds
  - 8 FAX
  - 6 by enforcing or adapting a standard calendar form when sending calendar entries
  - 3 if all handheld devices supported the same calendar file format
  - 2 if all handhelds used the same file format for transferring recorded audio
- 93% pass rate if all these issues were addressed



# Handheld – Handheld Aggregate: Transient Error Statistics

|                 |        |
|-----------------|--------|
| Potential Pairs | 36     |
| Tested Pairs    | 22     |
| Potential TC    | 248    |
| Tested TC       | 122    |
| TC w/ Errors    | 7      |
| Total Errors    | 27     |
| Error Rates     | 5.74%  |
| Average Errors  | 22.13% |

|     | HH1 | HH2 | HH3 | HH4 | HH5 | MP1 |
|-----|-----|-----|-----|-----|-----|-----|
| HH1 | 0   | 0   | 0   | 0   | 2   | 1   |
| HH2 | 8   | 0   | 0   | 4   | 0   | 3   |
| HH3 | 0   | 0   | 0   | 0   | 0   | 0   |
| HH4 | 0   | 0   | 0   | 0   | 0   | 4   |
| HH5 | 0   | 5   | 0   | 0   | 0   | 0   |
| MP1 | 0   | 0   | 0   | 0   | 0   | 0   |

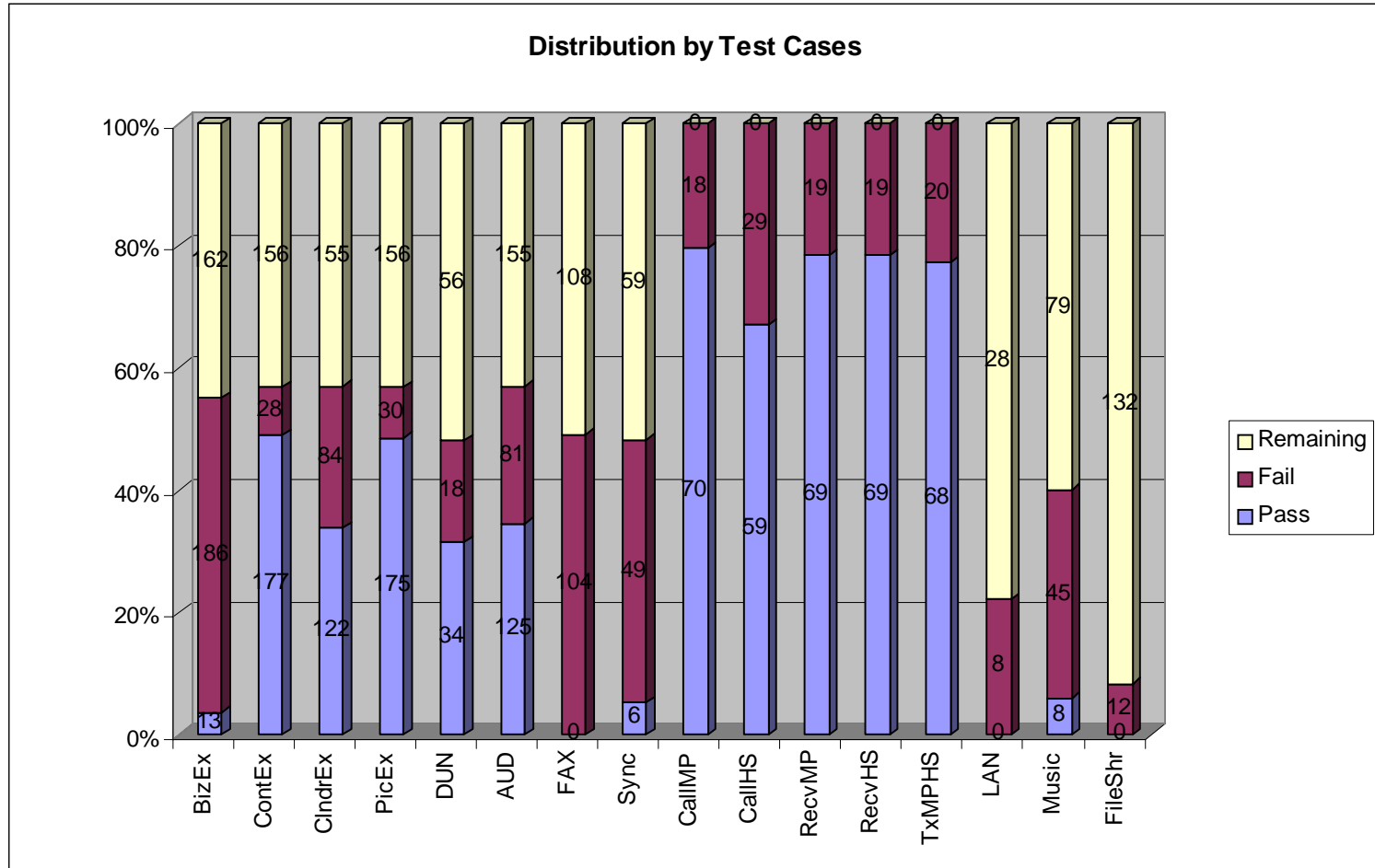
Note: Average Errors >> Error Rates, implying that errors are highly correlated.

# All Pairs Failure Rates

|      | HH1  | HH2 | HH3 | HH4 | HH5 | MP1 | MP2 | MP3 | MP4 | MP5 | MP6 | MP7 | MP8 | HS1  | HS2  | HS3  | HS4  | HS5  | HS6  | HS7  | HS8  | HS9  | HS10 | HS11 | PC1 | PC2 | PC3 | PC4 | PC5 | PC6 |     |      |     |      |     |      |      |      |      |      |      |     |
|------|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|------|------|------|------|------|------|------|------|------|------|-----|-----|-----|-----|-----|-----|-----|------|-----|------|-----|------|------|------|------|------|------|-----|
| HH1  |      | 40% |     | 40% | 57% | 71% | 71% | 71% | 57% |     | 71% | 43% |     |      |      |      |      |      |      |      |      |      |      |      |     |     |     |     |     |     |     |      |     |      |     |      |      |      |      |      |      |     |
| HH2  | 20%  |     | 80% | 20% | 80% | 43% | 43% | 43% | 29% | 43% | 43% | 29% | 43% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |     |     |     |     |     |     |     |      |     |      |     |      |      |      |      |      |      |     |
| HH3  |      | 40% |     | 60% |     |     |     |     |     |     |     |     |     |      |      |      |      |      |      |      |      |      |      |      |     |     |     |     |     |     |     |      |     |      |     |      |      |      |      |      |      |     |
| HH4  | 40%  | 0%  | 80% |     | 80% | 43% | 43% | 57% | 43% | 57% | 43% | 29% | 43% | 100% |      |      |      |      | 100% |      |      |      |      |      |     |     |     |     |     |     | 57% |      |     |      |     |      |      |      |      |      |      |     |
| HH5  | 50%  | 20% |     | 20% |     |     | 43% | 71% | 43% | 57% | 71% | 43% | 29% | 33%  | 33%  | 83%  | 33%  | 33%  | 33%  | 33%  | 33%  | 33%  | 33%  | 33%  |     |     |     |     |     |     | 43% |      |     |      |     |      |      |      |      |      |      |     |
| MP1  | 50%  | 33% |     | 33% |     |     | 57% | 57% | 43% | 20% | 57% |     |     | 17%  | 17%  | 17%  | 17%  | 17%  | 17%  | 17%  | 17%  | 17%  | 17%  | 17%  |     |     |     |     |     |     | 50% |      |     |      |     |      |      |      |      |      |      |     |
| MP2  | 67%  | 50% |     | 67% | 50% | 50% |     | 40% | 40% | 40% | 40% | 40% | 40% | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   |     |     |     |     |     |     | 57% | 100% |     |      |     |      |      |      |      |      |      |     |
| MP3  | 83%  | 50% |     | 67% | 67% | 33% | 20% |     | 20% | 20% | 20% | 20% | 20% | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   |     |     |     |     |     |     | 43% | 43%  |     |      |     |      |      |      |      |      |      |     |
| MP4  | 67%  | 50% |     | 67% | 50% | 33% | 20% | 20% |     | 20% | 20% | 20% | 20% | 0%   | 100% | 100% | 100% | 100% | 100% | 100% | 0%   | 0%   | 0%   | 0%   |     |     |     |     |     |     | 57% | 29%  |     |      |     |      |      |      |      |      |      |     |
| MP5  |      | 67% |     | 50% | 60% | 20% | 40% | 20% | 20% |     | 20% | 20% | 20% |      |      |      |      |      |      |      |      |      |      |      |     |     |     |     |     |     |     | 43%  | 71% | 57%  |     |      |      |      |      |      |      |     |
| MP6  | 50%  | 50% |     | 50% | 50% | 33% | 20% | 20% | 20% | 20% |     | 20% | 20% | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   |     |     |     |     |     |     | 43% | 43%  |     |      |     |      |      |      |      |      |      |     |
| MP7  | 100% | 50% |     | 50% | 50% |     | 20% | 20% | 20% | 20% | 20% |     | 20% | 0%   | 100% | 100% | 100% | 100% | 100% | 100% | 0%   | 0%   | 0%   | 0%   |     |     |     |     |     |     |     | 43%  | 71% | 57%  |     |      |      |      |      |      |      |     |
| MP8  |      | 50% |     | 50% | 50% |     | 20% | 20% | 20% | 20% | 20% | 20% |     | 0%   | 100% | 100% | 100% | 100% | 100% | 100% | 0%   | 0%   | 0%   | 0%   |     |     |     |     |     |     |     | 43%  | 71% | 57%  |     |      |      |      |      |      |      |     |
| HS1  |      |     |     |     |     |     |     |     |     |     |     |     |     |      |      |      |      |      |      |      |      |      |      |      |     |     |     |     |     |     |     |      |     |      |     |      |      |      |      |      |      |     |
| HS2  |      |     |     |     |     |     |     |     |     |     |     |     |     |      |      |      |      |      |      |      |      |      |      |      |     |     |     |     |     |     |     |      |     |      |     |      |      |      |      |      |      |     |
| HS3  |      |     |     |     |     |     |     |     |     |     |     |     |     |      |      |      |      |      |      |      |      |      |      |      |     |     |     |     |     |     |     |      |     |      |     |      |      |      |      |      |      |     |
| HS4  |      |     |     |     |     |     |     |     |     |     |     |     |     |      |      |      |      |      |      |      |      |      |      |      |     |     |     |     |     |     |     |      |     |      |     |      |      |      |      |      |      |     |
| HS5  |      |     |     |     |     |     |     |     |     |     |     |     |     |      |      |      |      |      |      |      |      |      |      |      |     |     |     |     |     |     |     |      |     |      |     |      |      |      |      |      |      |     |
| HS6  |      |     |     |     |     |     |     |     |     |     |     |     |     |      |      |      |      |      |      |      |      |      |      |      |     |     |     |     |     |     |     |      |     |      |     |      |      |      |      |      |      |     |
| HS7  |      |     |     |     |     |     |     |     |     |     |     |     |     |      |      |      |      |      |      |      |      |      |      |      |     |     |     |     |     |     |     |      |     |      |     |      |      |      |      |      |      |     |
| HS8  |      |     |     |     |     |     |     |     |     |     |     |     |     |      |      |      |      |      |      |      |      |      |      |      |     |     |     |     |     |     |     |      |     |      |     |      |      |      |      |      |      |     |
| HS9  |      |     |     |     |     |     |     |     |     |     |     |     |     |      |      |      |      |      |      |      |      |      |      |      |     |     |     |     |     |     |     |      |     |      |     |      |      |      |      |      |      |     |
| HS10 |      |     |     |     |     |     |     |     |     |     |     |     |     |      |      |      |      |      |      |      |      |      |      |      |     |     |     |     |     |     |     |      |     |      |     |      |      |      |      |      |      |     |
| HS11 |      |     |     |     |     |     |     |     |     |     |     |     |     |      |      |      |      |      |      |      |      |      |      |      |     |     |     |     |     |     |     |      |     |      |     |      |      |      |      |      |      |     |
| PC1  |      |     |     |     |     |     | 57% | 57% | 57% |     | 57% |     |     | 0%   |      |      |      |      |      |      |      |      |      |      |     |     |     |     |     |     |     |      | 43% | 100% | 50% | 17%  | 0%   |      |      |      |      |     |
| PC2  |      |     |     |     |     |     | 80% | 20% | 43% | 50% | 43% | 33% |     | 43%  |      | 100% |      |      |      |      |      |      |      |      |     |     |     |     |     |     |     |      |     |      |     | 100% |      | 100% | 100% | 100% |      |     |
| PC3  |      |     |     |     |     |     |     |     |     |     |     |     |     |      |      |      |      |      |      |      |      |      |      |      |     |     |     |     |     |     |     |      |     |      |     |      | 100% | 100% |      | 100% | 100% |     |
| PC4  | 100% |     |     |     |     |     |     |     |     |     |     |     |     |      |      |      |      |      |      |      |      |      |      |      |     |     |     |     |     |     |     |      |     |      |     |      |      | 17%  | 100% | 100% |      |     |
| PC5  | 20%  | 0%  |     |     |     |     |     |     |     |     |     |     |     |      |      |      |      |      |      |      |      |      |      |      |     |     |     |     |     |     |     |      |     |      |     |      |      |      | 33%  | 50%  | 100% |     |
| PC6  | 40%  | 20% |     |     |     |     |     |     |     |     |     |     |     |      |      |      |      |      |      |      |      |      |      |      |     |     |     |     |     |     |     |      |     |      |     |      |      |      |      | 17%  | 50%  | 83% |

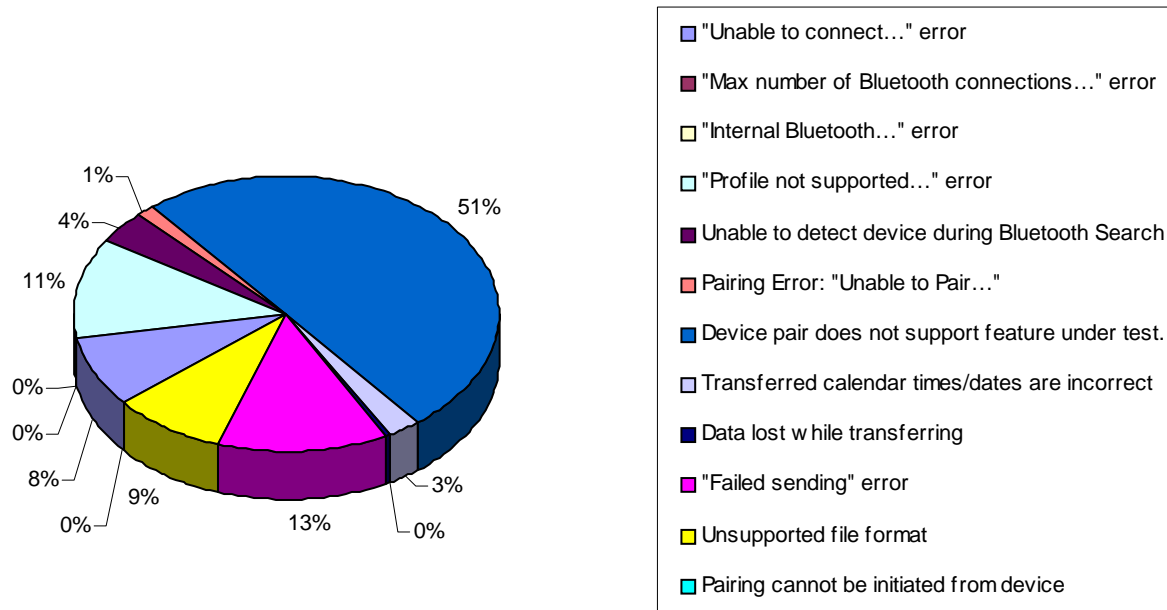


# Distribution by Test Cases



# Failure Breakdowns

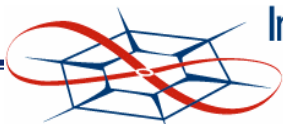
## Failure Breakdown over all Test Cases



# All Test Cases: Summary

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- Summary
  - Overall pass rate of 57.02% (995 of 1745)
    - 377 (50.3%) of failures are due to unsupported features
      - Some can be solved by managing expectations
      - Some can be solved by providing capability to the user interface
  - Failure Breakdowns (509 of 750 failures)
    - 169 if all devices were able to support and initiate a business card exchange
    - 104 FAX tests
    - 84 if headsets and mobile phones used the same profiles
    - 64 if all devices supported the same audio, picture, calendar, and contact file format.
    - 46 if mobile phones, handhelds, and PCs could all initiate and support synchronization.
    - 23 if recurring interoperability problems with PC3 are corrected.
    - 19 handhelds, mobile phones, and PCs adapted the same format when sending calendar entries.
  - 86.2% Pass rate by addressing these issues



# All Test Cases: Implications

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- Failure Implications
  - Key: improving feature support OR managing user expectations of features
  - Many of the interoperability problems are solved on the application software level
  - Less than 20% of all failures may be due to actual low-level Bluetooth issues
    - “Failed sending” permanent error (98 failures, 13%)
    - “Unable to detect device during Bluetooth search” permanent error (62 failures, 8.3%)
  - Errors are highly correlated, indicating lower-level Bluetooth problems
  - Failure to track FDP and/or usability issues may give pessimistic results

## Criticisms and Conclusions

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- Failure to track FDP caused premature failure declarations
- Imperfect classification of observations
- Primitive analysis, limited by current tools, tests
- Choice of test cases
- Weighting results by relative “importance”
- Representative samples, disclosure limitations