1. Certifiable Wireless Data Buses

2. Autonomous Navigation

Vic Thomas

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Certifiable Wireless Data Buses

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- **Objective: Replace wired avionics data buses with wireless data buses**
  - **Can we replace a wired bus such as ARINC 629 with a wireless equivalent?**

- **Rationale:**
  - **Reduced weight**
    - Translates to lower fuel costs
  - **Ease of re-configurability of aircraft**
  - **Lower installation and maintenance costs**

Wireless Data Buses on Aircraft: State of the Practice

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- **Wireless data buses are being used for**
  - **Cabin entertainment systems**
    - Reduces cost associated with changing seat pitch, seasonal changes in configuration (number of 1st class seats)
  - **Lavatory smoke detectors**
    - Today airplanes have superfluous wiring to accommodate different configurations used by different airlines
  - **Cargo hold smoke detectors**
  - **Emergency lighting system**

All wireless data buses used today are for non-critical applications

Wireless Data Buses for Critical Applications

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- **The wireless data bus must be:**
  - **Reliable**
  - **Available**
  - **Protects data integrity**
  - **Deterministic**
    - Bounded delivery times, low jitter
  - **Secure**
    - Low susceptibility to denial-of-service attacks (jamming)
    - Authenticated messages
    - Encryption?
  - **Non-interference**
    - Must not interfere with existing radios and avionics
  - **Certifiable**
    - If a data bus does not have the above properties it will be extremely difficult to certify any application that uses it

Challenges

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- **Certification is the biggest challenge**
- **Requirements are not well understood**
  - **E.g.: “How much” jamming resilience is required?**
    - How is this specified?
    - How “jamming resistant” are today’s avionics when personal radios are not allowed on board
- **Lack of a good understanding of the faults suffered by wireless networks**
- **Current certification processes are inadequate**
  - **Limited to understanding the effects of on-board wireless systems on existing radios and avionics**
- **Where in the RF spectrum should these networks operate?**
  - **The only globally available frequency band is the 2.4 GHz ISM band**
- **Requires a change in the mind-set of the certification authorities**
  - **Knee-jerk reaction is to reject anything wireless as being inherently un-certifiable**

Designing a Wireless Data Bus

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- **Given any dependability and security requirements it is possible to design a wireless data bus that meets those requirements**
- **Will such a bus deliver adequate bandwidth?**
  - **Techniques used to improve dependability and security typically result in reduced bandwidth**

Commonly Used Techniques for Dependability and Security

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- A combination of techniques will be needed to meet dependability, determinism and security requirements
- Different techniques provide tolerance for different kinds of faults and are implemented at different layers of the protocol stack

Techniques for Jamming Resistance

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- **Spread spectrum techniques**
  - **Spread energy over larger part of the spectrum**
  - **Frequency hopping and Direct Sequence Pseudo Noise are commonly used**
    - Time Hop and Transform Domain spread spectrum techniques less common
- **Typically use combination of techniques**
  - **Frequency hopping + direct sequence**
    - Permits use of wide-spaced bands (hop among bands and spread energy within band)
- **For additional protection, send same bit(s) over multiple frequency hops**
  - **Keeps a narrow-band jammer from taking out a part of the communication**
- **For Frequency Hopping, hopping sequence must not be guessable**
  - **Cryptographic techniques**
    - Can't guess seed of random number generator by observing generated numbers
  - **Re-seed all random number generators during scheduled maintenance**

Techniques for Reliability, Determinism and Security

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- **Physical/Link layer**
  - Bits transmitted over multiple frequency hops
  - Determinism
- **Network layer: At least N independent pre-computed routes between any two nodes**
  - Tolerates failures on nodes
- **Application layer: Control applications that can tolerate delayed or lost messages**
- **Security**
  - Needed for authentication and possibly encryption
  - Aircraft wide-key, changed during scheduled maintenance

Ongoing Efforts

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- A consortium of aerospace companies including Honeywell is working with the FAA on certification issues
- The RTCA SC-202 committee is studying the effects of on-board radios on avionics an other air to ground radio systems
  - Radios at different frequencies and radios that turn on and off
- NASA and the European Space Agency have been characterizing the RF environment on-board aircraft
- Research on control over unreliable communication links

It's only a matter of time before we see wireless network based critical systems.

Autonomous Navigation

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Autonomous Navigation

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- Honeywell, as a leader in navigation technologies is pursuing business in the area of autonomous navigation
- Potential markets include
  - Military
  - Mining
  - Mowing
  - …
- We are currently working with a major manufacturer of mowers and a university to develop an autonomous mower
  - Golf courses: fairway mowing

Autonomous Mowing of Fairways

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- **Less challenging than many of the autonomous systems we heard about this week**
  - **Relatively benign terrain**
  - **Well known terrain**
    - Good topological maps
  - **Possible to install navigation infrastructure**
    - GPS/RTK
  - **Possible to install communication infrastructure**
    - Mower to operator station

Challenges

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- Safety!
  - Golfers, fauna
- Precision Navigation
  - Parallel cuts, signature cuts
  - Claim: 5cm position accuracy
- Sensing
  - Obstacles
    - Small objects, uncontrolled lighting
  - Fairway edges
- Poor mower dynamics
  - Stopping distance ~5m at 2-3 m/s

- Reliable communications with a mobile base station
- User interfaces
  - Barely literate groundskeepers
  - Supervisor in maintenance building is typically computer literate
- Marketability
  - Cost: one time and recurring
  - US export controls prevent use of certain inertial navigation technologies