Closing the Link

Communication System Technology Developments

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Challenges
Current Comms Challenges

• Increase data transfer
  – Increase data rate
  – Increase contact time

• Operate in constellations/clusters
  – Inter-satellite interference
  – Communication with multiple satellites

• Finding a solution within CubeSat constraints is very challenging
  – Form, Fit, Function
  – Programmatics (time & money available)

• Do better in a more challenging environment
The QB50 example

- Initiative lead by von Karman Institute
- Constellation of 50 2U Cubesats
- Single launch deployment
  - 300 km, 80° inclination
  - 3 - 12 weeks lifetime
- In-situ measurement of the lower thermosphere
  - Standard sensors suite
  - Measurement during orbit decay
- Expected KO Q4 2011
- Expected launch 2013-2014
ISIS in QB50

- Launch service providers
- Communication WP

Main interface between:
- Launcher
- Cubesat teams
- Ground stations
Challenges in QB50

• Launch
• Operations
• Communications
Challenges in QB50

• Launch
  – 50 Cubesats in one launch
  – 50 development teams
  – Different mass, ballistic coefficient, etc...
  – Possible collisions between satellites

• Operations

• Communications
Challenges in QB50

- Launch
- Operations
  - Extremely short lifetime (3 - 12 weeks)
  - Extremely short commissioning (~ 1 day)
  - Short satellite passes:
    7 min max at the beginning
    4 ÷ 5 min max at the end
  - TLE not reliable during decay
  - Scientific data cannot be lost
- Communications
Challenges in QB50

- Launch
- Operations
- Communications
  - 10 ÷ 30 sats visible at the beginning at the same time
  - 2 ÷ 5 sats visible at the end at the same time
  - Limited spectrum available (Radio Amateur bands, VHF / UHF / S)
  - Limited power onboard
  - Single satellite tracking is not efficient
Software Defined Radio

- Move complexity to Software
- Standard hardware platform
- High flexibility (modulation / datarate)
- Simple reconfiguration / upgrade

SDR Transmitter / Transceivers

Ground station Transceiver
Software Defined Radio

• Bandwidth efficient modulations:
  – BPSK, QPSK
  – Variable datarate: 1.2 ÷ 1000 kbit/s
  – Good performances with noise

• Advanced channel access mechanisms can be used
  – FDMA & TDMA can have a lower efficiency (frequency drift, clock drift)
  – CDMA can be a viable alternative
Code Division Multiple Access

- Used in 3G phones
- Spectrum is spread over a wider bandwidth using a pseudo-random noise generator
- Less interferences due to narrow-band signals
Increase contact time

- Ground station network
  - Automatic data delivery
  - Ex: RASCAL, GENSO
- All limited to 1 satellite at once
  - Limiting factor for QB50
  - Requires ground station capable to receive multiple satellites at once
  - Massive increase in contact time
Omnidirectional ground station

- Tracking ground station has limited field of view
  - Limited by antenna beamwidth
- Omni-directional ground station can monitor the whole sky
  - Simultaneous multiple satellite reception: 10 ÷ 20 in QB50
  - Requires a more complex receiver
    Multiple simultaneous SDR receivers
  - TLE are not necessary:
    They can even be computed!
Omnidirectional ground station

- Omni-directional
  - Cheap setup, easy installation
  - Omni-directional antenna: ~3 dB gain
  - Low datarate: 1.2 ÷ 9.6 kbit/s
  - Simple requirements for roof mounting: no moving antennas, small area required
  - Multiple receivers
  - Medium computational power required
  - Can compute satellite TLEs
  - GPS receiver for precise frequency, time and position reference
Higher Speed: S-band

- Wider bandwidth available
  - Amateur: 2 MHz
  - Commercial: requires license

- High datarate possible
  - $38k4 \div 1000$ kBit/s

- Short contact time
  - 5 min pass
  - $6 \div 18$ Mbyte per pass
S-band

• Communication is limited by average power consumption (~1.5 W avg per orbit)
• Attitude control may be needed depending on satellite antenna
  – Complex during orbit decay
  – Can be compensated with a higher antenna gain on ground
• Downlink in radio-ham frequencies or commercial S-band (shared)
  – Maximum speed should be traded with available bandwidth and number of users
Next Generation Transceivers

- **TrxUV/TRXVU**
  - High output power (up to 1 W)
  - BPSK and QPSK
  - Fully software defined transmitter

- **Availability:** H1 2012
Next Generation Transmitters

• TXS-100/1000
  – Fully software defined transmitter
  – BPSK, QPSK and GMSK capable
  – Datarate up to 1Mbit/s
  – > 27 dBm output power
  – < 4 W power consumption

• Availability:
  – 38k4: Now
  – 100 kbit/s: Q4 2011
  – 1 Mbit/s: Q2 2012
Next Generation Ground systems

• Completely software defined
  – Datarate, modulation and frequency agile
  – Replacement for out of stock ICOM-910H
  – Wideband receiver, datarates up to 1 Mbit/s available

• VHF / UHF / S-band
  – Up to 3 m dish
  – Radome available for hostile environments

• Central control console for easy operations

• Omnidirectional systems investigated
Conclusions

• Challenges
  – Do better in a more challenging environment
  – Maximizing data received within challenging CubeSat constraints
  – Operate constellations

• Solutions
  – System level optimization
  – New technology implementations on ground and in space

• Current technology and smart solutions can solve these problems
Code Division Multiple Access

- Pseudo-random noise helps in spreading the bandwidth
- If the pseudo-random sequence is known, data can be de-spread
- If the sequence is unknown, the signal looks like white noise
- Multiple sources can use the same channel without interference
Channel coding

- **FEC gives high gain in link budget**
  - AO-40: ~5 dB gain @ BER = 10^{-6}
  - AO-40: 40% code rate

- **Limited use in Cubesats**
  - Usually link budgets were not critical, a higher antenna gain or output power was possible
  - Channels are usually bandwidth limited
  - AX-25 does not support it natively (FX-25)
  - Added complexity, longer development time
Channel coding in QB50

• It does not need to be compliant with AX-25
  – No TNC available for BPSK, QPSK
  – SDR or soundcard modem needed
  – Protocol should be public
    freely available software decoder would be a plus

• Many new developments in the amateur world are going this way (ARISSat)
  – AX25-like protocol, with convolutional codes
S-band

- Communication is limited by average power consumption (~1.5 W avg per orbit)
  - 5 ÷ 10 W power consumption for few minutes every orbit
  - Only one ground station contact per orbit
- Attitude control may be needed depending on satellite antenna
  - Complex during orbit decay
  - Can be compensated with a higher antenna gain on ground
- Requires precise TLEs
  - Complex during orbit decay
  - Use VHF/UHF beacon for more precise tracking
Omnidirectional ground station

- Beam steering antenna array
  - No moving parts
  - High gain
  - Multiple satellites visible: 10 ÷ 20
  - Requires a quite complex receiver
    Multiple simultaneous SDR receivers
  - High computational power required