Do It Yourself Proximity Warning Device

Brief outlook on the concept, design and test prototype

Presented by «Linar Laboratories»

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Table of content

- Idea
- Theory
- Hardware
- Software
- Prototype
- Testing
- Further information

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Idea

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Goals

- Meet assigned tech. specifications
- No soldering skills required to build device
- Parts are easily available at local store, e-store, Ebay or Taobao
- No h/w tools required to install firmware(s)
- Application software is h/w independent, simple enough to be altered by a user

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Technical specifications

- Operation range:
  - at least within 1.5 kilometers in radius
- Tracking:
  - at least 7 objects simultaneously
- «From-Position-to-Mark» latency:
  - not more than 2-3 seconds

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Choices of ISM band radio inter-communication

- «RF Module» (868/915 MHz)
- ZigBee (868/915 MHz or 2.4Ghz)
- Wi-Fi (2.4Ghz or 5.8Ghz)
- ADS-B (ES 1090Mhz or UAT 978Mhz)*

* ADS-B is not at ISM band(s). It operates at one of «aviation» frequencies.

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

«RF Module» (868/915 MHz)

PROS

- Great «range to power consumption» ratio
- Compact size
- Same band that FLARM* already uses

CONS

- Only a few USB-to-RF dongles are available on the market, most are «short range»
- No common, transparent interface to Linux

* FLARM® - is a registered trademark of FLARM Technology GmbH.

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

ZigBee (868/915 MHz or 2.4Ghz)

PROS

- Great «range to power consumption» ratio
- Compact size

CONS

- Only a few USB-to-RF devices are available on the market, most are relatively expensive
- No common, transparent interface to Linux yet

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Wi-Fi (2.4Ghz or 5.8Ghz)

PROS

- Good range at reasonable power consumption
- Numerous USB-to-WiFi «extended range» devices are available on the market
- Great unified interface in Linux for data capture/injection (mac80211)
- Low price for «mass products»

CONS

- Some countries apply limitations on transmission power or outdoor use
- Reception noise level can be high near congested areas due to wi-fi hotspots, microwave equipment, etc.

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

ADS-B (ES 1090Mhz or UAT 978Mhz)

PROS

- Becoming a standard for aviation use within next few years (EU till 2018, US till 2020)

CONS

- No transceivers available on the mass product market yet
- No common, transparent interface to Linux

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Decision

- Make use Wi-Fi technology first
- Keep an eye on RF868/915 and ZigBee, modular USB design will allow to detach Wi-Fi then attach another RF hardware if necessary
- Think about and try to make few steps toward further transition onto ADS-B (ES 1090)

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Hardware inter-connectivity

In order to

- meet «no soldering» requirement
- make use a variety of inexpensive mass products available on the market
- to satisfy limited space constraints

decision is to utilize USB Bus as a primary internal hardware interface.

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Theory

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Radio signal attenuation

Reduction in power of an electromagnetic wave as it propagates through space can be estimated by:

$$\mathcal{L} = 20 \log_{10} \left(\frac{4\pi d}{\lambda} \right)$$

where

- $\mathcal{L}$ - is the path loss in decibels,
- λ - is the wavelength,
- d - is the transmitter-receiver distance in the same units as the wavelength

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Path loss for typical ISM bands

- 868 MHz (EU)

Distance, km	1	2	3	4	5
$\mathcal{L}$, dB	91	97	101	103	105

- 915 MHz (US)

Distance, sm	1	2	3	4	5
$\mathcal{L}$, dB	96	102	105	108	110

- 2.4GHz

Distance, km	1	2	3	4	5
$\mathcal{L}$, dB	100	106	110	112	114

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

868MHz vs. 2.4GHz

PROS

- Transmitter at 868MHz needs 9dBm less power for the same range, or 3X range for same power than 2.4 GHz transmitter

CONS

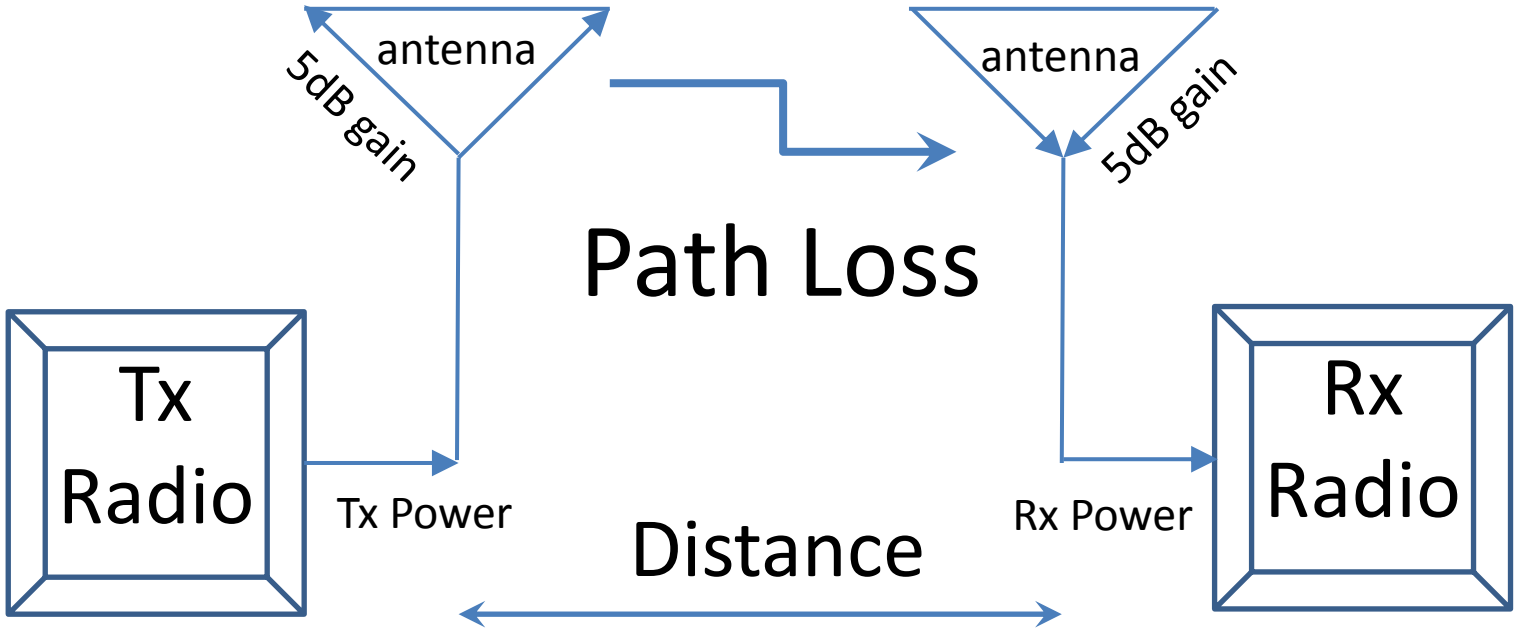
- Wavelength at 868MHz is 2.8X longer than at 2.4GHz, so 2.4GHz omnidirectional antenna's gain of the same size is higher

TOTAL

- **System** at 868MHz gives approx. 1.5X (3dB) increase in range at the same power and same antennas size

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Wireless Distribution System



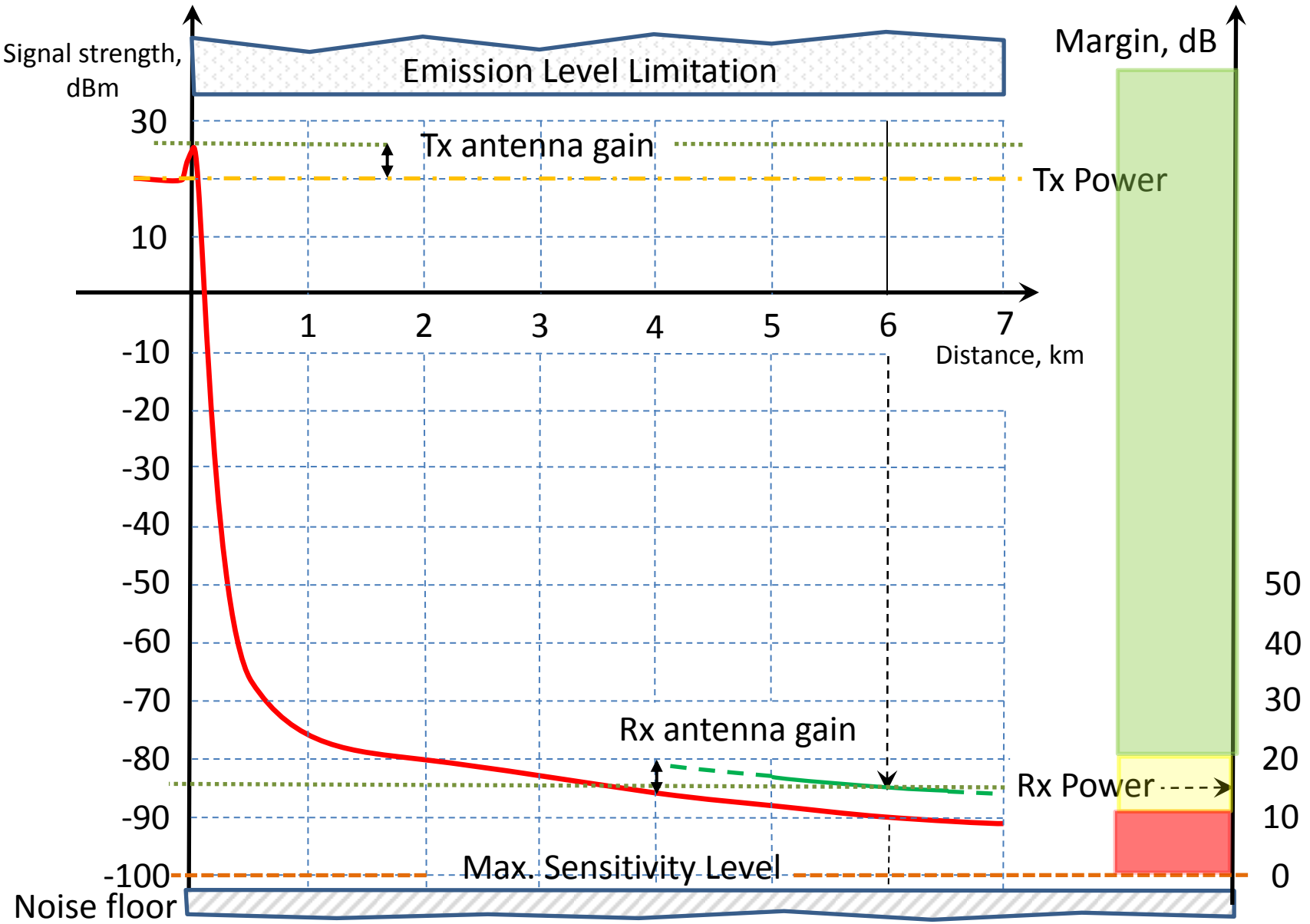
Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Reception Signal Quality

- Margin – is the ratio by which the Rx signal exceeds the minimum amount for proper operation
- How typical Wi-Fi margin values affect reception quality:

Margin, dB	<10	10-20	>20
Reception quality	*No*	*Poor*	*Good*

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com



Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Examples of regional 2.4GHz emission limitations

IMPORTANT NOTICE!

It is responsibility of the operator of an electronic device to comply with local emission regulations!

EU (ETSI)

- Max EIRP: 20 dBm;

US (FCC)

For Tx antenna gain ≤ 6 dbi:

- Max Tx Power: 30 dBm;
- Max EIRP: 36 dBm;

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

ETSI range

Provided that Receiver has

- Antenna gain: 5dBi, and
- Sensitivity: -100 dBm

Distance, km	1	1.6	3	4	5
$\mathcal{L}$, dB	100	104	110	112	114
Rx power, dBm	-75	-79	-85	-87	-89
Margin, dB	25	21	15	13	11

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

FCC range

Provided that Receiver has

- Antenna gain: 5dBi, and
- Sensitivity: -100 dBm

Distance, sm	1	3	5	8	10
$\mathcal{L}$, dB	104	114	118	122	124
Rx power, dBm	-63	-73	-77	-81	-83
Margin, dB	37	27	23	19	17

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Long range USB Wi-Fi adapter

Alfa Networks AWUS036H

FCC ID: UQ2AWUS036H
Emission Type: DSSS/OFDM
Wireless: IEEE 802.11b/g
Sensitivity 802.11b 1 Mbps (B/QPSK): - 96dBm
typically @PER < 8%
packet size 1024 and
@25ºC + 5ºC
Max. output power: 24.5dBm (by FCC test)
EIRP : 29-30dBm (with 5dBi antenna)
Linux support:
full-featured “mac80211” open-source driver with packets capture/injection

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Alfa AWUS036H range

- Max Tx Power: 24 dBm by FCC test ;
- Sensitivity: -96 dBm ;
- Tx antenna gain: 5dBi , EIRP: 29 dBm ;
- Rx antenna gain: 5dBi ;

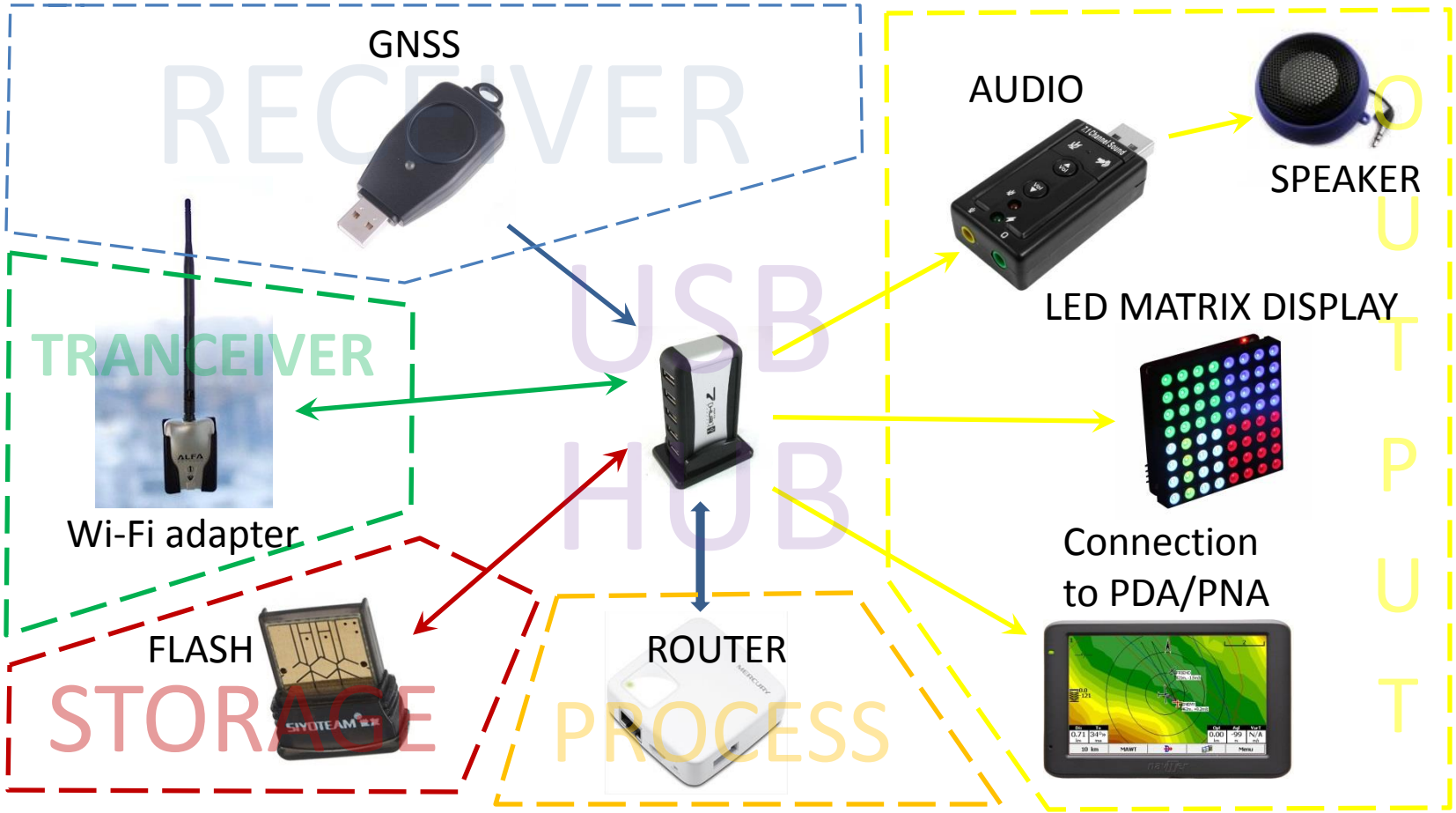
Distance, km sm	1.6 1	2.9 1.8	4.8 3	8 5	12.8 8
$\mathcal{L}$, dB	104	109	114	118	122
Rx power, dBm	-70	-75	-80	-84	-88
Margin, dB	26	21	16	12	8

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Hardware

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Standard components overview



Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Processing module

Brand

- TP-Link

Model

- TL-WR703N

Features

- Atheros AR7240 32-bit CPU (MIPS) @400Mhz
- Atheros integrated wireless 802.11 b/g/n
- 4 MB flash memory
- 32 MB RAM
- USB 2.0 port
- Tiny form factor: 5.7cm x 5.7cm x 1.8cm
- 0.5W power consumption (average)
- Supported by OpenWrt (Linux) project

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Equivalents of WR703N available on other markets

Mercury MW151RM-3G

Fast FWR171-3G

TP-Link MR3020

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Storage module

The router being used as a processing module has limited internal storage size.

Software pack that manages the system requires 50-100 Mbytes of permanent memory to store programs and data.

USB-Drive provides enough memory to meet this requirement.

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

GNSS module

There are numerous USB GPS or GLONASS «dongles» available on the consumer's market.

Standard Linux GPSd software is employed in this system to receive geo-positional data from the device.
This gives opportunity to support almost any of these «dongles».

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Bus interconnect

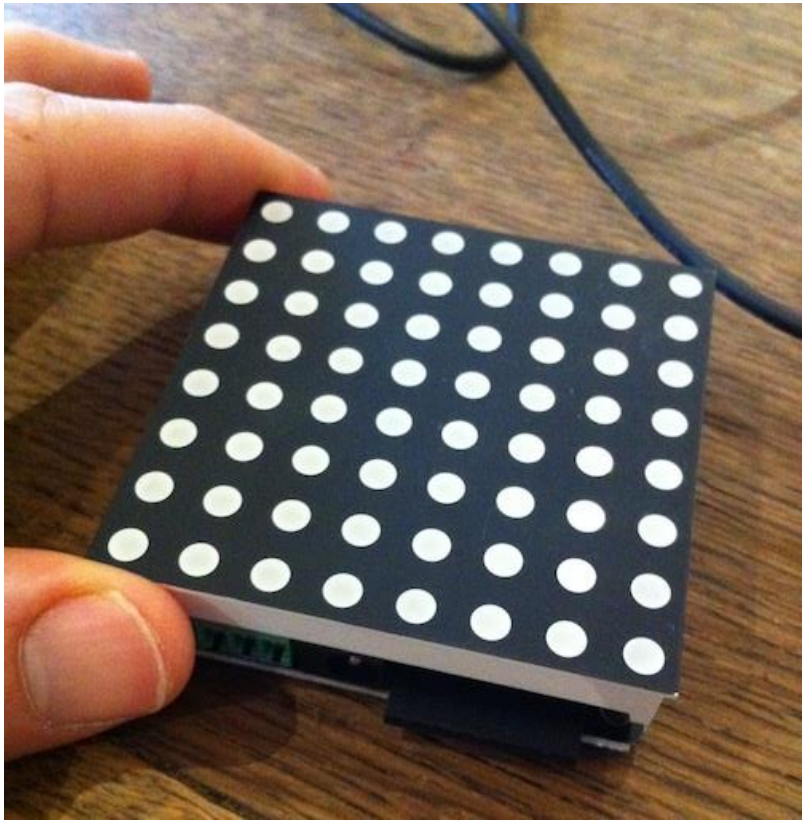
Since the system consists of several devices, all of them need to be electrically connected .

Minimum 7-port USB hub is required.

Power to the system is supplied through the hub.

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

USB Display



The display consists of:

- 60x60mm 8x8 RGB LED matrix (on top) ;
- USB LED display controller (on the bottom) ;

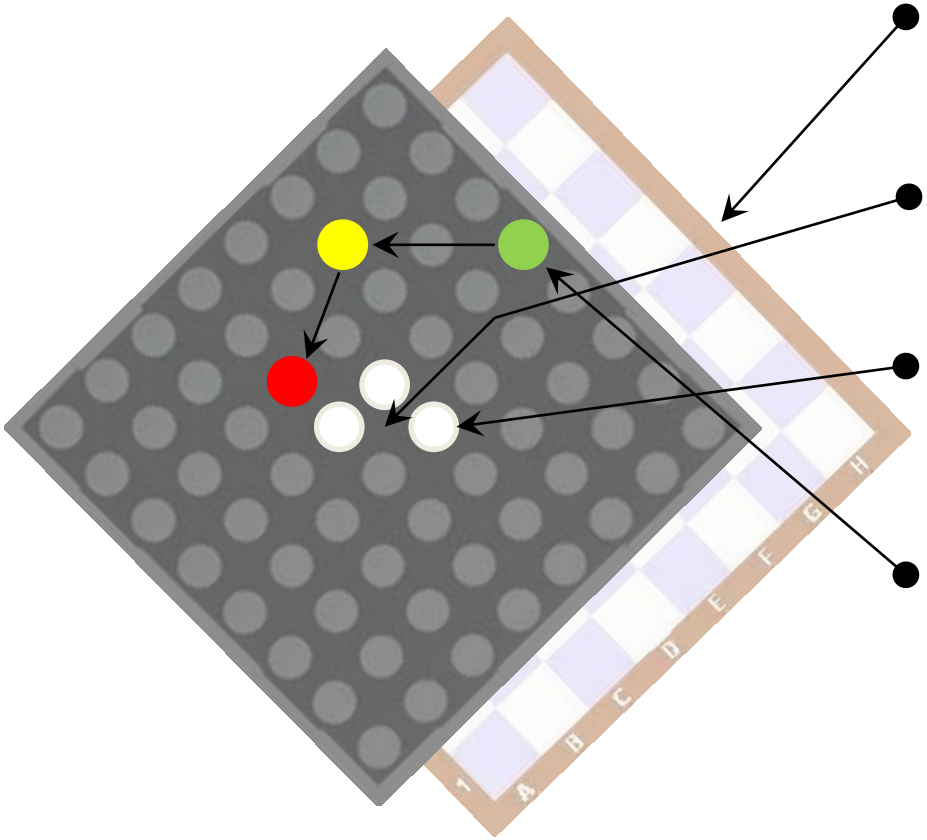
The controller is either:

- «*Rainbowduino*» by Seeed Studio, or ;
- «*Colorduino*» by Itead Studio ;

- both are supported.

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

LED display purpose



- The display depicts a «chess board» been rotated at 45 degrees ;
- Position of the observer is in the center of the «board» ;
- Three white colored LEDs in the center of display depicts an «arrow» in the direction of motion (or «north-up») ;
- Red, yellow and green LEDs depicts a traffic in the vicinity of observer ;

«Closer to center» means «closer to observer», warning level is color-encoded ;

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

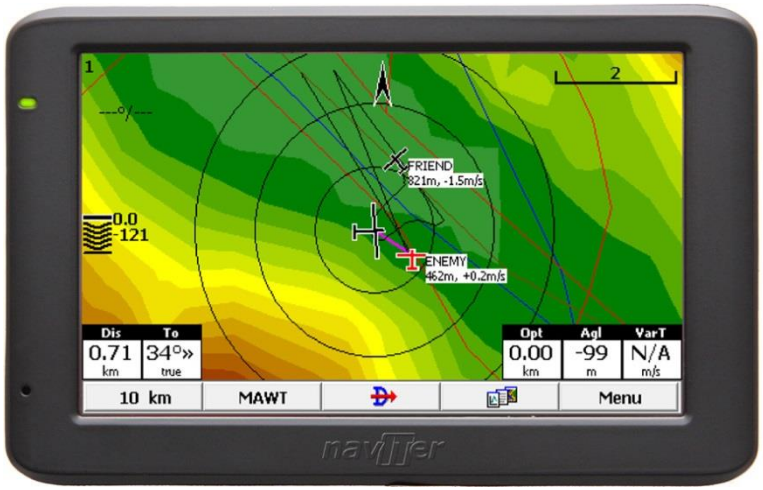
Audio module

USB Sound Card is employed to provide voice and audio traffic alerts for sailplane pilots with no necessity to look at the instrument panel.

The speaker delivers these alerts from device to the pilot’s ears.

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Output to external gadget



The system is capable to provide output of traffic positions and proximity alerts to external «Personal Assistants» such as PDA, PNA, PGA and other.

To transfer this information to an «Assistant» a USB cable or USB Bluetooth dongle can be used.

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

ADS-B module (optional)

In the areas where the volume of airlines traffic is high it could make sense to receive alerts on proximity of these heavy jets.

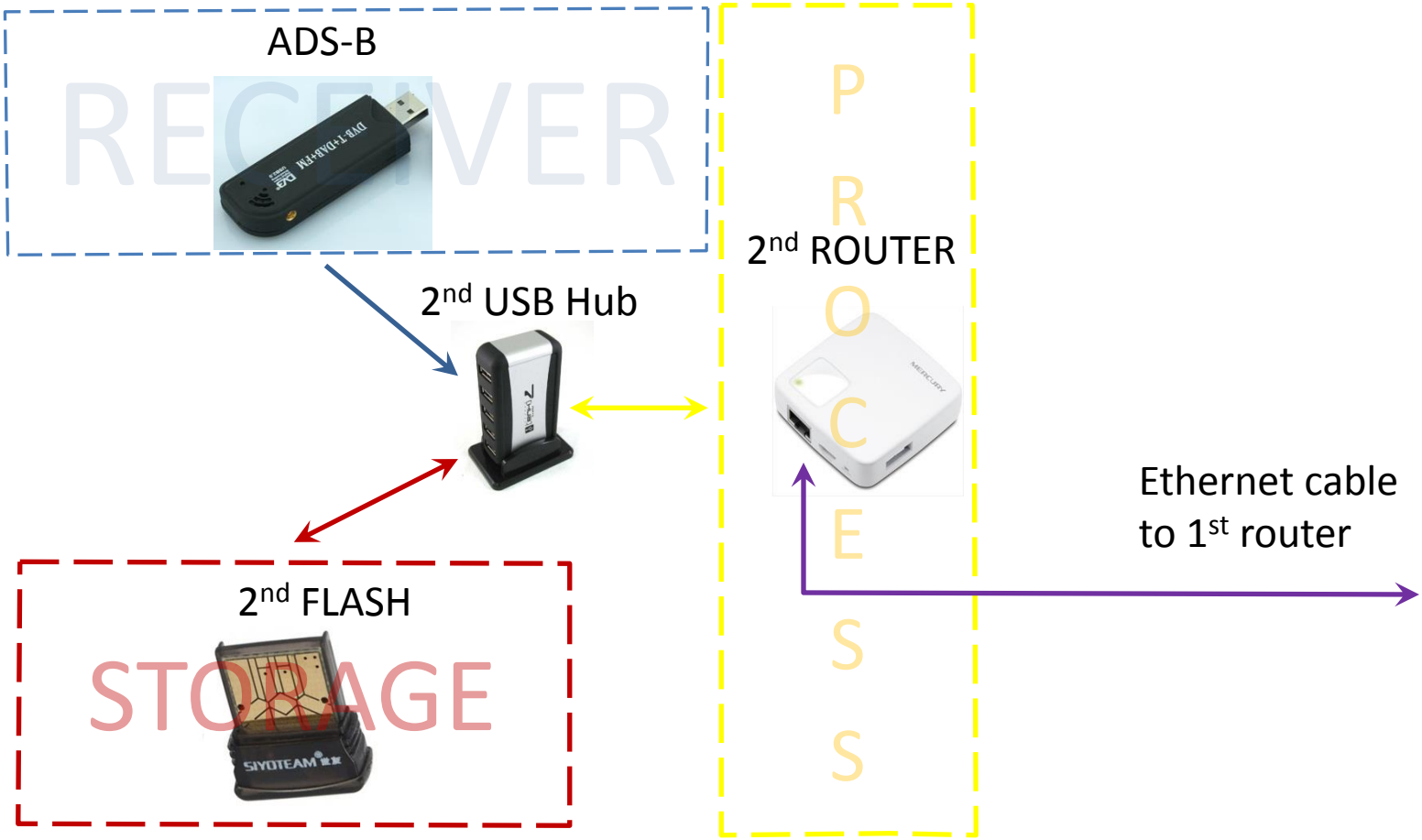
There are few USB DVB-T TV sticks available on the market that are known to receive ADS-B signals (1090 MHz), filter them out of noise, amplify, digitize then deliver to a computer for processing.

This system employs the device as an optional source of traffic information. Receive-only, no transmission is available.

Due to high CPU power and RAM memory consumption necessary for decoding of ADS-B an additional processing module is in use.

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

ADS-B subsystem overview



Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Software

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Overview

Application software:

- This software drives the system components to perform the specified task;
- It is mostly developed by the author of this presentation ;
- It is written in Python programming language ;

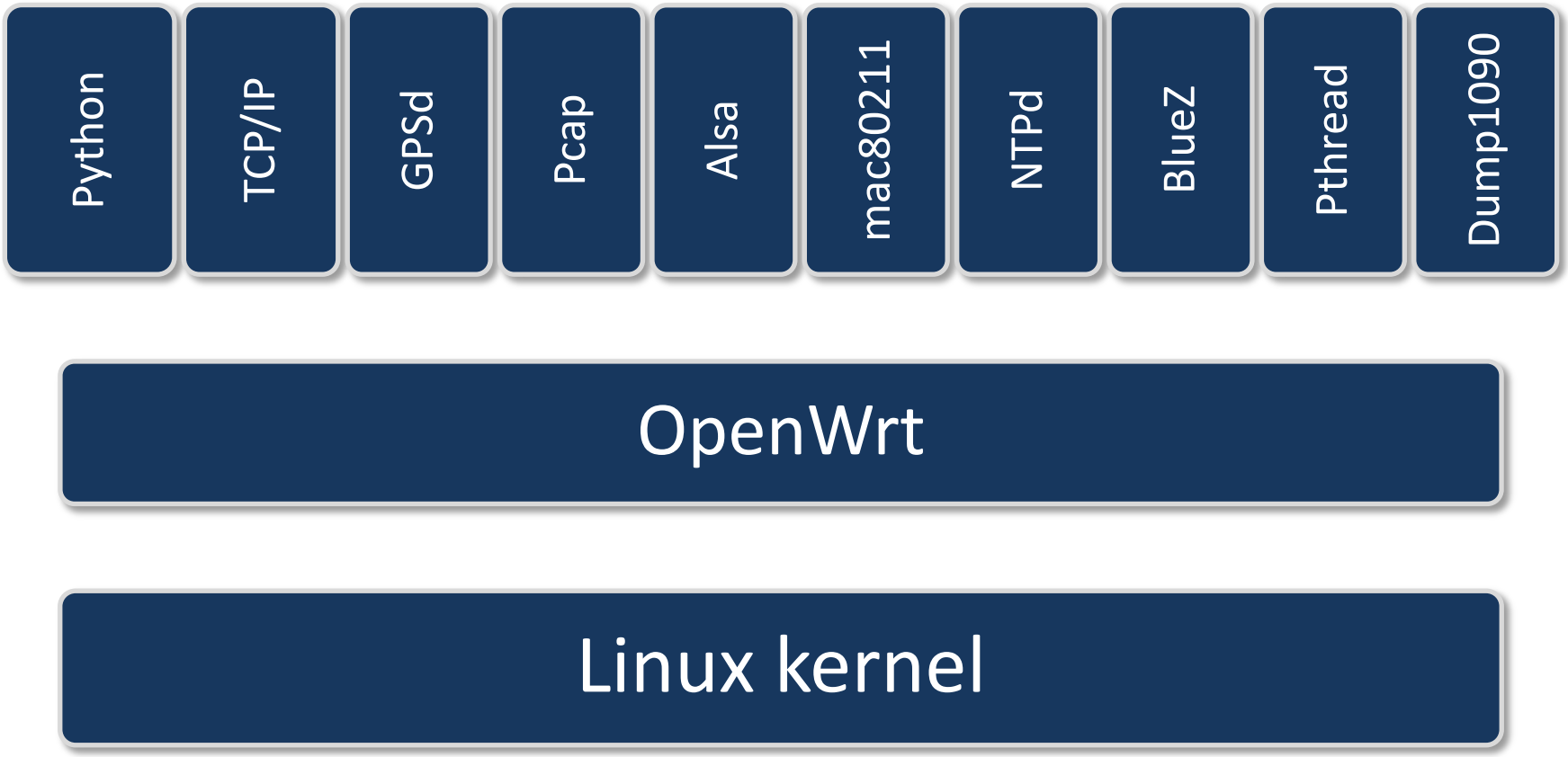
System software consists of:

- Firmware for processing module ;
- Operating System extension for processing module ;
- Firmware for LED display module ;

System software is primarily developed by Linux/OpenWrt and Arduino communities.

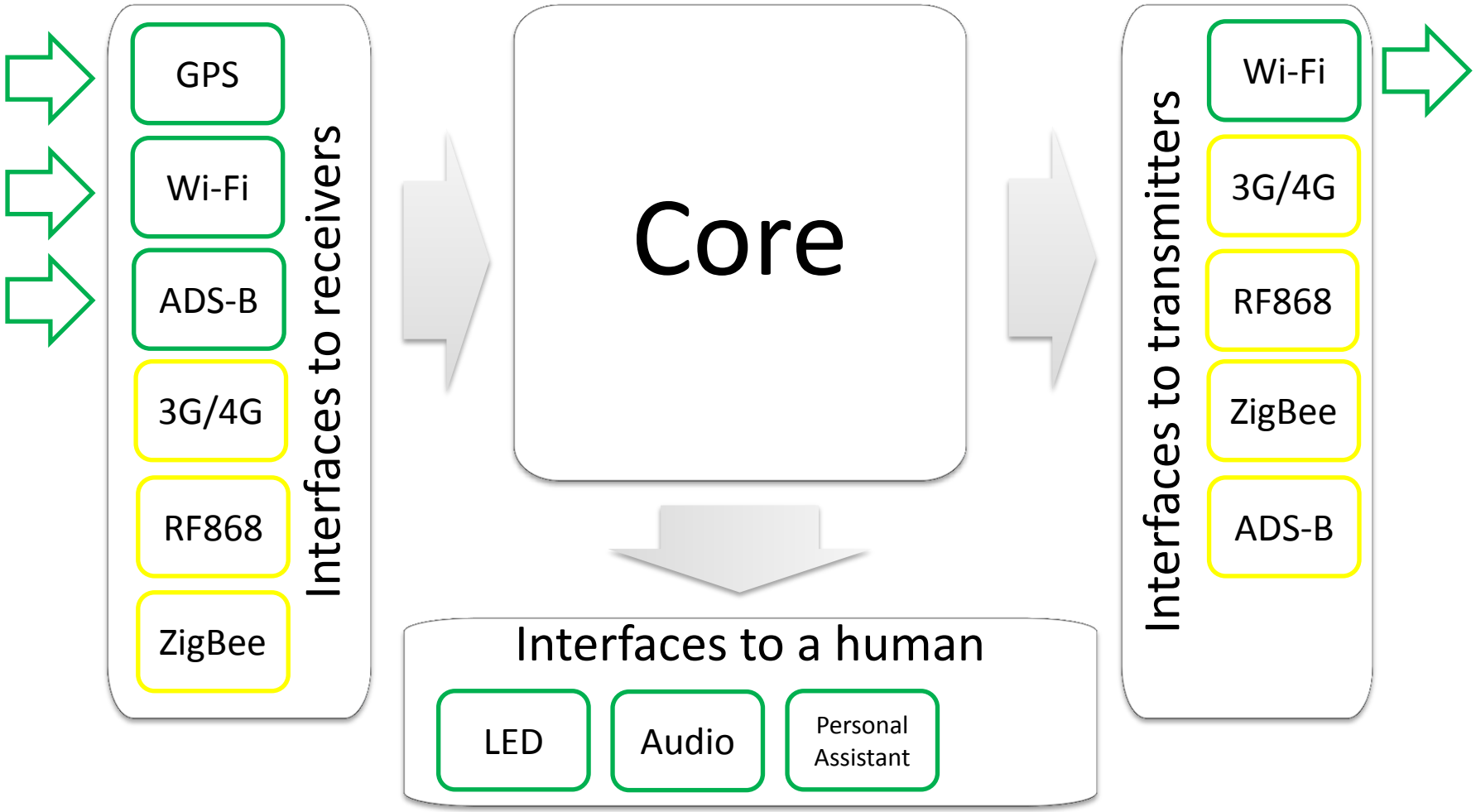
Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

System software



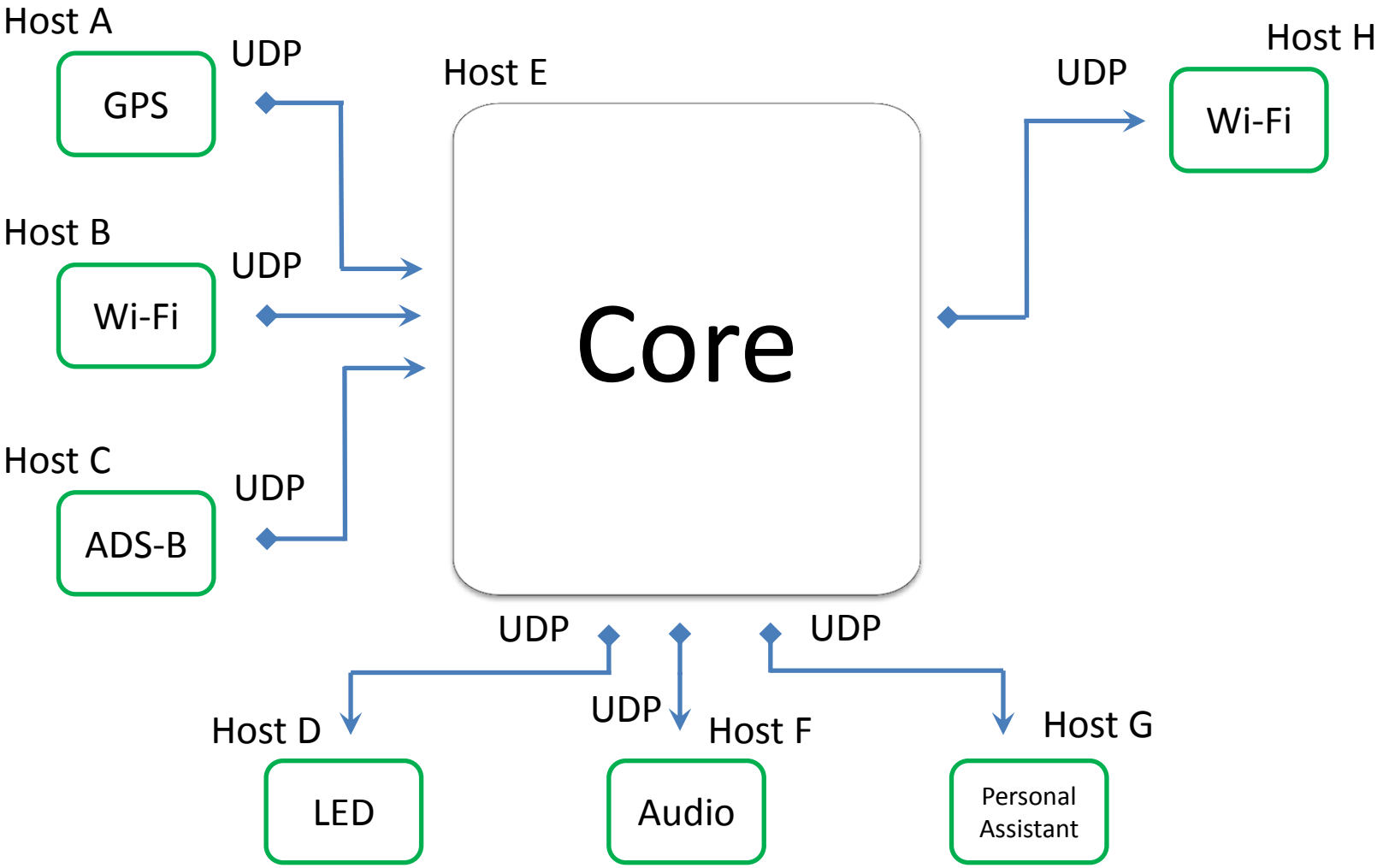
Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Application software



Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Distributed software net



Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Core overview

Flight Progress «Strips Board»

«Vectors Board»

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Strips board

Time (UTC)	A/C ID	Position	Alt.	…
15:25:01.5	RA	N52.885201 E036.206278	1510	
15:25:01.7	OY	N52.887855 E036.213337	1743	
15:25:02.1	ZK	N52.88726 E036.192649	1476	
15:25:02.5	CY	N52.878196 E036.197327	1822	

- The «strips board» represents most recent flight progress information about all the traffic in the vicinity of observer, one «strip» per one aircraft;
- Observer's aircraft (if any) is also represented in the list;
- The board is updated on a regular basis by new information coming from receiving sources;
- Core submits full content of the board to transmitters for radio broadcasting at a given rate per second;

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Vectors board

Distance	Bearing	Elevation	A/C ID	…
331	47	-114	OY	
486	153	671	CP	
2533	314	229	RA	

- This «board» provides vectors pointing to all the traffic in the vicinity of observer;
- The data is represented in relation to position of the observer's aircraft ;

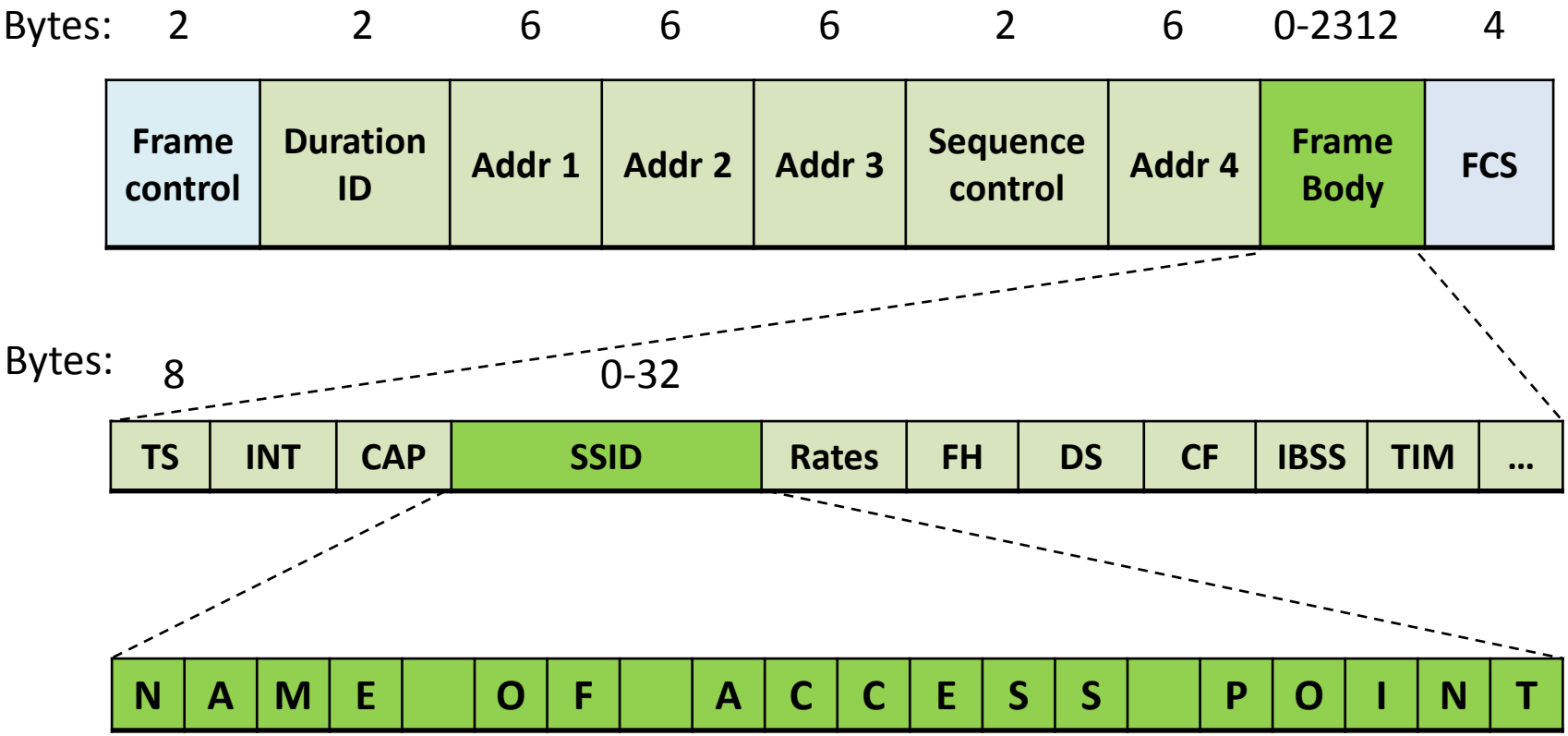
Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Interface to Wi-Fi

- This system uses Linux «radiotap» API to achieve direct 802.11 frame injection and reception;
- Within variety of all 802.11 features only beacon management frames are employed;
- Beacons are broadcasted repeatedly at a certain time interval;
- While in a traditional Wi-Fi network the beacon's content is relatively constant, in this system the beacons are dynamic;
- To achieve maximum operation range the beacons are emitted at the maximum allowed power setting and at the minimum data rate;

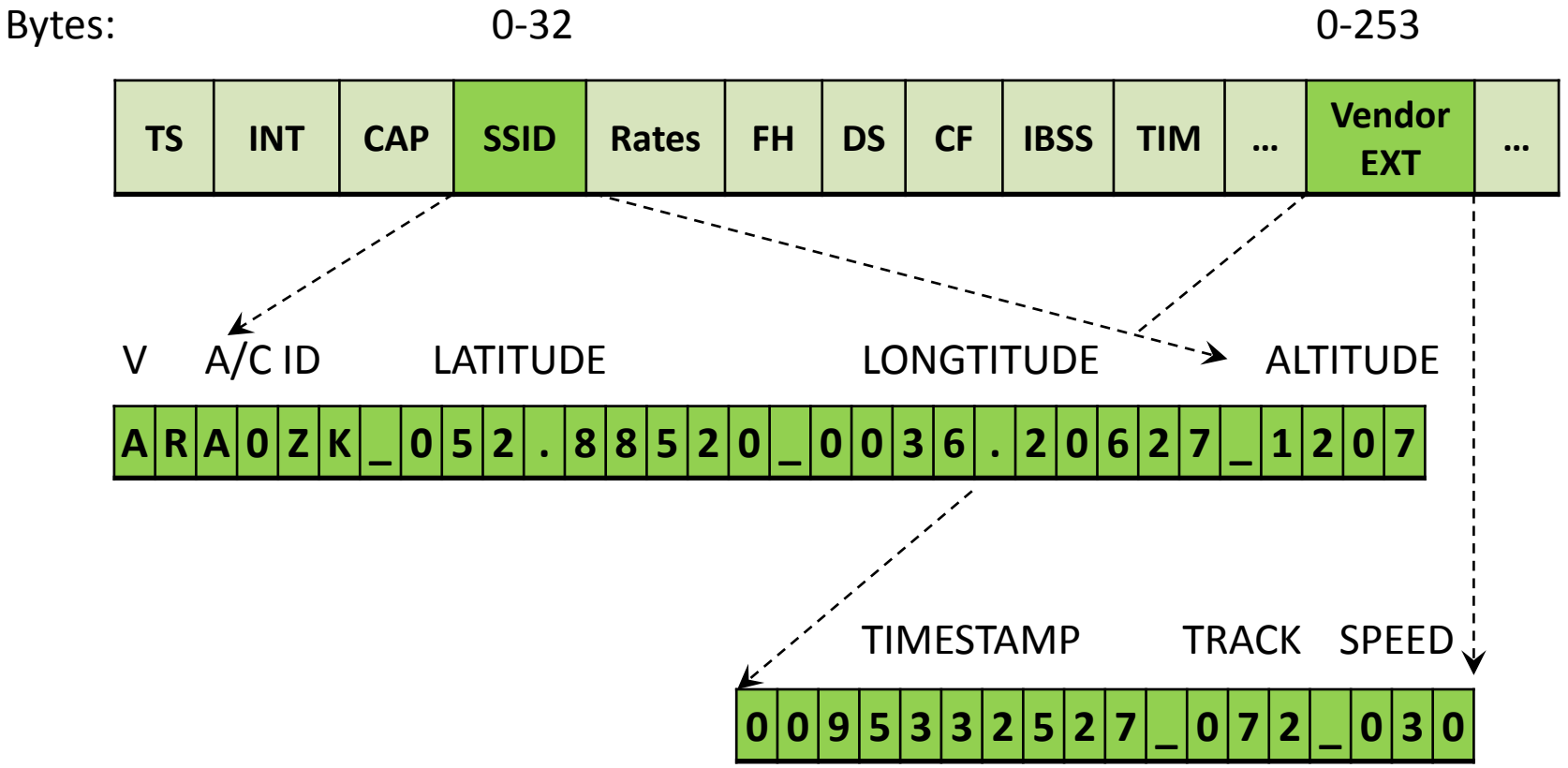
Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

802.11 beacon frame format



Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Advanced use of 802.11 beacon frame



Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Operation range update

- The technical specification for the long-range Wi-Fi adapter states that :

  Sensitivity is - 96dBm typically @PER < 8%

  and packet size 1024

- Since this system uses beacon frames of only 100 bytes in length or less, the equivalent sensitivity will be few decibels higher ;
- Thus a slight increase in actual operation range is expected ;

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Prototype

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Prototype

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Testing

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com

Thank you for your attention!

For more details about the topics presented in this slideshow, please, visit:

TBD

For software source code, please, visit:

https://github.com/lyusupov/Argus

Author: Linar R. Yusupov; © 2013 ; e-mail: linar.r.yusupov@gmail.com