

# Link Budget Analysis for IEEE 802.22b

IEEE P802.22 Wireless RANs

Date: 2012-05-14

## Authors:

| Name             | Company            | Address   | Phone          | email                                   |
|------------------|--------------------|---|----------------|---|
| Shigenobu Sasaki | Niigata University | 8050 Igarashi 2-no-cho, Nishi-ku, Niigata<br>950-2181 Japan | 81-25-262-6737 | shinsasaki@ieee.org                     |
| Bingxuan Zhao    | Niigata University |   |                | zhaobx@telecom0.eng.<br>niigata-u.ac.jp |
|                  |                    |   |                |   |

**Notice:** This document has been prepared to assist IEEE 802.22. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.

**Release:** The contributor grants a free, irrevocable license to the IEEE to incorporate material contained in this contribution, and any modifications thereof, in the creation of an IEEE Standards publication; to copyright in the IEEE's name any IEEE Standards publication even though it may include portions of this contribution; and at the IEEE's sole discretion to permit others to reproduce in whole or in part the resulting IEEE Standards publication. The contributor also acknowledges and accepts that this contribution may be made public by IEEE 802.22.

**Patent Policy and Procedures:** The contributor is familiar with the IEEE 802 Patent Policy and Procedures <http://standards.ieee.org/guides/bylaws/sb-bylaws.pdf> including the statement "IEEE standards may include the known use of patent(s), including patent applications, provided the IEEE receives assurance from the patent holder or applicant with respect to patents essential for compliance with both mandatory and optional portions of the standard." Early disclosure to the Working Group of patent information that might be relevant to the standard is essential to reduce the possibility for delays in the development process and increase the likelihood that the draft publication will be approved for publication. Please notify the Chair **Apurva Mody** <[apurva.mody@ieee.org](mailto:apurva.mody@ieee.org)> as early as possible, in written or electronic form, if patented technology (or technology under patent application) might be incorporated into a draft standard being developed within the IEEE 802.22 Working Group. **If you have questions, contact the IEEE Patent Committee Administrator at [patcom@ieee.org](mailto:patcom@ieee.org).**

## Abstract

- **IEEE 802.22 TGb has discussed the Functional Requirement Document (FRD) and Selection Criteria (SC) document.**
- **Low-complexity and high-complexity CPEs are newly defined in TGb FRD for mainly metering and monitoring applications.**
- **This contribution provides some information of preliminary link budget analysis for discussion of FRD and SC document, especially on low-complexity and high-complexity CPEs.**

## Key Technical Issues

- **Regulatory constraints**
  - Stringent out-of-band emission mask
  - Power spectral density (PSD) limit
- **Two class of CPE is define to cover various applications**
  - Low-complexity CPE and High-complexity CPE
  - **Detail function seems still under development**
- **Support at least 2048 CPEs**

Table 1 Key spectrum mask elements in TVWS (FCC 3<sup>rd</sup> MO&O)

| Type of TV bands device          | Power limit<br>(6 MHz) | PSD limit<br>(100 kHz) | Adjacent channel<br>limit (100 kHz) |
|----------------------------------|------------------------|------------------------|-------------------------------------|
| Fixed                            | 30 dBm (1 Watt)        | 12.6 dBm               | -42.8 dBm                           |
| Personal/portable (adj. channel) | 16 dBm (40 mW)         | -1.4 dBm               | -56.8 dBm                           |
| Sensing only                     | 17 dBm (50 mW)         | -0.4 dBm               | -55.8 dBm                           |
| All other personal/portable      | 20 dBm<br>(100 mW)     | 2.6 dBm                | -52.8 dBm                           |

## Link budget Assumptions

- **Minimum receiver sensitivity requirement for QPSK rate: 1/2 at BER=  $2 \times 10^{-4}$  (Ref. 1, Table 231, 6MHz BW)**
  - Base station receiver sensitivity:  $-94.5$  (dBm)
  - CPE receiver sensitivity:  $-91.3$  (dBm)
    - H-CPE and L-CPE: same receiver sensitivity
- **Upstream is mainly considered.**
  - Using several subchannels among 60 subchannels (24+4 subcarriers (Ref. 1, Fig. 13))
- **Channel Model**
  - LOS: Free-space path loss (ideal model)
  - NLOS: Modified Okumura-Hata model [2]
    - Time and location probabilities are not considered as in ITU-R P1546-1 model [3].

## Link Budget in LOS channel (1)

- **Fixed CPE -> Base station (Fixed) (non-adjacent channel)**
  - Receiver sensitivity: -94.5 dBm

**Table 2 Achievable communication distance (in km)**

| Fixed (Upstream)       |         | Antenna Gain= 6 (dBi)  |                    |                    |                    |                     |                   |                     |
|------------------------|---------|------------------------|--------------------|--------------------|--------------------|---------------------|-------------------|---------------------|
| Center Frequency [MHz] |         | Signal Bandwidth [kHz] |                    |                    |                    |                     |                   |                     |
|                        |         | 93.734<br>1 sub-ch     | 187.47<br>2 sub-ch | 374.94<br>4 sub-ch | 749.88<br>8 sub-ch | 1499.8<br>16 sub-ch | 2812<br>30 sub-ch | 5436.6<br>58 sub-ch |
| 66                     | (4ch)   | 158.27                 | 223.83             | 316.54             | 447.66             | 633.09              | 866.89            | 1205.4              |
| 85                     | (6ch)   | 122.89                 | 173.79             | 245.78             | 347.59             | 491.57              | 673.11            | 935.93              |
| 177                    | (7Ch)   | 59.01                  | 83.46              | 118.03             | 166.92             | 236.06              | 323.24            | 449.45              |
| 213                    | (13Ch)  | 49.04                  | 69.35              | 98.08              | 138.71             | 196.16              | 268.61            | 373.49              |
| 473                    | (14ch)  | 22.08                  | 31.23              | 44.16              | 62.46              | 88.33               | 120.96            | 168.19              |
| 515                    | (21 ch) | 20.28                  | 28.68              | 40.56              | 57.37              | 81.13               | 111.09            | 154.47              |
| 596                    | (35 ch) | 17.52                  | 24.78              | 35.05              | 49.57              | 70.1                | 95.99             | 133.48              |
| 695                    | (51 ch) | 15.03                  | 21.25              | 30.06              | 42.51              | 60.12               | 82.32             | 114.46              |

## Link Budget in LOS channel (2)

- **Fixed CPE <->Fixed CPE (non-adjacent channel)**
  - Receiver sensitivity: -91.3 dBm

**Table 3 Achievable communication distance (in km)**

| Fixed (Upstream)       |         | Antenna Gain= 6 (dBi)  |                    |                    |                    |                     |                   |                     |
|------------------------|---------|------------------------|--------------------|--------------------|--------------------|---------------------|-------------------|---------------------|
| Center Frequency [MHz] |         | Signal Bandwidth [kHz] |                    |                    |                    |                     |                   |                     |
|                        |         | 93.734<br>1 sub-ch     | 187.47<br>2 sub-ch | 374.94<br>4 sub-ch | 749.88<br>8 sub-ch | 1499.8<br>16 sub-ch | 2812<br>30 sub-ch | 5436.6<br>58 sub-ch |
| 66                     | (4ch)   | 109.48                 | 154.82             | 218.95             | 309.64             | 437.91              | 599.62            | 833.74              |
| 85                     | (6ch)   | 85.004                 | 120.21             | 170.01             | 240.43             | 340.02              | 465.59            | 647.38              |
| 177                    | (7Ch)   | 40.821                 | 57.73              | 81.643             | 115.46             | 163.29              | 223.59            | 310.89              |
| 213                    | (13Ch)  | 33.922                 | 47.973             | 67.844             | 95.946             | 135.69              | 185.8             | 258.34              |
| 473                    | (14ch)  | 15.276                 | 21.603             | 30.551             | 43.206             | 61.104              | 83.668            | 116.34              |
| 515                    | (21 ch) | 14.03                  | 19.841             | 28.06              | 39.683             | 56.12               | 76.844            | 106.85              |
| 596                    | (35 ch) | 12.123                 | 17.145             | 24.246             | 34.289             | 48.493              | 66.401            | 92.327              |
| 695                    | (51 ch) | 10.396                 | 14.703             | 20.793             | 29.405             | 41.586              | 56.942            | 79.175              |

## Link Budget in LOS channel (3)

- **Portable CPE -> Base station, non-adjacent channel**
  - Operating only in 21-51 TV ch
  - Sensitivity: -94.5 dBm

**Table 4 Achievable communication distance (in km)**

| Portable (Upstream)       |         | Antenna Gain= 0 (dBi)  |                    |                    |                    |                     |                   |                     |
|---------------------------|---------|------------------------|--------------------|--------------------|--------------------|---------------------|-------------------|---------------------|
| Center Frequency<br>[MHz] |         | Signal Bandwidth [kHz] |                    |                    |                    |                     |                   |                     |
|                           |         | 93.734<br>1 sub-ch     | 187.47<br>2 sub-ch | 374.94<br>4 sub-ch | 749.88<br>8 sub-ch | 1499.8<br>16 sub-ch | 2812<br>30 sub-ch | 5436.6<br>58 sub-ch |
| 515                       | (21 ch) | 3.21                   | 4.54               | 6.42               | 9.09               | 12.85               | 17.6              | 24.48               |
| 596                       | (35 ch) | 2.77                   | 3.92               | 5.55               | 7.85               | 11.11               | 15.21             | 21.15               |
| 695                       | (51 ch) | 2.38                   | 3.36               | 4.76               | 6.73               | 9.52                | 13.04             | 18.14               |

## Link Budget in LOS channel (4)

- **Portable CPE -> Fixed and portable CPE, non-adjacent channel**
  - Receiver sensitivity: -91.3 dBm

**Table 5 Achievable communication distance (in km)**

| Portable (Upstream)    |         | Antenna Gain= 0 (dBi)  |                    |                    |                    |                     |                   |                     |  |
|------------------------|---------|------------------------|--------------------|--------------------|--------------------|---------------------|-------------------|---------------------|--|
| Center Frequency [MHz] |         | Signal Bandwidth [kHz] |                    |                    |                    |                     |                   |                     |  |
|                        |         | 93.734<br>1 sub-ch     | 187.47<br>2 sub-ch | 374.94<br>4 sub-ch | 749.88<br>8 sub-ch | 1499.8<br>16 sub-ch | 2812<br>30 sub-ch | 5436.6<br>58 sub-ch |  |
| 515                    | (21 ch) | 2.2236                 | 3.1446             | 4.4472             | 6.2893             | 8.8945              | 12.179            | 16.934              |  |
| 596                    | (35 ch) | 1.9214                 | 2.7173             | 3.8428             | 5.4345             | 7.6857              | 10.524            | 14.633              |  |
| 695                    | (51 ch) | 1.6477                 | 2.3302             | 3.2954             | 4.6604             | 6.5909              | 9.0247            | 12.548              |  |



## Link Budget in LOS channel (5)

- **Portable CPE -> Portable CPE, adjacent channel**
  - Transmit PSD limit : -1.4dBm/100kHz
  - Receiver sensitivity: -91.3 dBm

**Table 6 Achievable communication distance (in km)**

| Portable (Upstream)    |         | Antenna Gain= 0 (dBi)  |                    |                    |                    |                     |                   |                     |
|------------------------|---------|------------------------|--------------------|--------------------|--------------------|---------------------|-------------------|---------------------|
| Center Frequency [MHz] |         | Signal Bandwidth [kHz] |                    |                    |                    |                     |                   |                     |
|                        |         | 93.734<br>1 sub-ch     | 187.47<br>2 sub-ch | 374.94<br>4 sub-ch | 749.88<br>8 sub-ch | 1499.8<br>16 sub-ch | 2812<br>30 sub-ch | 5436.6<br>58 sub-ch |
| 515                    | (21 ch) | 1.403                  | 1.9841             | 2.806              | 3.9683             | 5.612               | 7.6844            | 10.685              |
| 596                    | (35 ch) | 1.2123                 | 1.7145             | 2.4246             | 3.4289             | 4.8493              | 6.6401            | 9.2327              |
| 695                    | (51 ch) | 1.0396                 | 1.4703             | 2.0793             | 2.9405             | 4.1586              | 5.6942            | 7.9175              |

## Link Budget in NLOS channel (1)

- **Fixed CPE -> Base station (non-adjacent channel)**
  - Receiver sensitivity: -94.5 dBm
- **NLOS (Modified Hata Model, Ref. 2.)**
  - Tx antenna height: 0.5 m; Rx antenna height: 30 m

**Table 7 Achievable communication distance (in km)**

| Fixed (Upstream)       |         | Antenna Gain= 6 (dBi)  |          |          |          |           |           |           |
|------------------------|---------|------------------------|----------|----------|----------|-----------|-----------|-----------|
| Center Frequency [MHz] |         | Signal Bandwidth [kHz] |          |          |          |           |           |           |
|                        |         | 93.734                 | 187.47   | 374.94   | 749.88   | 1499.8    | 2812      | 5436.6    |
|                        |         | 1 sub-ch               | 2 sub-ch | 4 sub-ch | 8 sub-ch | 16 sub-ch | 30 sub-ch | 58 sub-ch |
| 66                     | (4ch)   | 11.026                 | 13.426   | 16.326   | 19.876   | 23.626    | 27.626    | 32.326    |
| 85                     | (6ch)   | 9.526                  | 11.576   | 14.076   | 17.176   | 20.776    | 24.276    | 28.526    |
| 177                    | (7Ch)   | 6.126                  | 7.426    | 9.076    | 11.026   | 13.426    | 16.026    | 19.376    |
| 213                    | (13Ch)  | 5.426                  | 6.576    | 8.026    | 9.776    | 11.876    | 14.226    | 17.126    |
| 473                    | (14ch)  | 3.376                  | 4.076    | 4.976    | 6.076    | 7.376     | 8.826     | 10.626    |
| 515                    | (21 ch) | 3.226                  | 3.926    | 4.776    | 5.776    | 7.026     | 8.426     | 10.176    |
| 596                    | (35 ch) | 2.976                  | 3.626    | 4.376    | 5.376    | 6.526     | 7.776     | 9.376     |
| 695                    | (51 ch) | 2.726                  | 3.326    | 4.076    | 4.926    | 6.026     | 7.176     | 8.676     |

## Link Budget in NLOS channel (2)

- **Fixed CPE -> Fix or Portable CPE (non-adjacent channel)**
  - Receiver sensitivity: -91.3 dBm
- **NLOS (Modified Hata Model, Ref. 2.)**
  - Tx antenna height: 0.5 m; Rx antenna height: 30 m

**Table 8 Achievable communication distance (in km)**

| Fixed (Upstream)       |         | Antenna Gain= 6 (dBi)  |          |          |          |           |           |           |
|------------------------|---------|------------------------|----------|----------|----------|-----------|-----------|-----------|
| Center Frequency [MHz] |         | Signal Bandwidth [kHz] |          |          |          |           |           |           |
|                        |         | 93.734                 | 187.47   | 374.94   | 749.88   | 1499.8    | 2812      | 5436.6    |
|                        |         | 1 sub-ch               | 2 sub-ch | 4 sub-ch | 8 sub-ch | 16 sub-ch | 30 sub-ch | 58 sub-ch |
| 66                     | (4ch)   | 8.926                  | 10.876   | 13.226   | 16.126   | 19.626    | 23.026    | 27.076    |
| 85                     | (6ch)   | 7.726                  | 9.376    | 11.426   | 13.926   | 16.926    | 20.226    | 23.826    |
| 177                    | (7Ch)   | 4.976                  | 6.026    | 7.326    | 8.926    | 10.876    | 13.026    | 15.676    |
| 213                    | (13Ch)  | 4.376                  | 5.326    | 6.526    | 7.926    | 9.626     | 11.526    | 13.926    |
| 473                    | (14ch)  | 2.726                  | 3.326    | 4.026    | 4.926    | 5.976     | 7.176     | 8.626     |
| 515                    | (21 ch) | 2.576                  | 3.176    | 3.876    | 4.676    | 5.726     | 6.826     | 8.226     |
| 596                    | (35 ch) | 2.426                  | 2.926    | 3.576    | 4.326    | 5.276     | 6.326     | 7.626     |
| 695                    | (51 ch) | 2.226                  | 2.726    | 3.276    | 4.026    | 4.876     | 5.826     | 7.026     |

## Link Budget in NLOS channel (3)

- **Portable CPE -> Base station, non-adjacent channel**
  - Operating only in 21- 51 TV chs.
  - Sensitivity: -94.5 dBm
- **NLOS (Modified Hata Model, Ref. 2.)**
  - Tx antenna height: 0.5 m; Rx antenna height: 30 m

**Table 9 Achievable communication distance (in km)**

| Portable (Upstream)    |         | Antenna Gain= 0 (dBi)  |                    |                    |                    |                     |                   |                     |
|------------------------|---------|------------------------|--------------------|--------------------|--------------------|---------------------|-------------------|---------------------|
| Center Frequency [MHz] |         | Signal Bandwidth [kHz] |                    |                    |                    |                     |                   |                     |
|                        |         | 93.734<br>1 sub-ch     | 187.47<br>2 sub-ch | 374.94<br>4 sub-ch | 749.88<br>8 sub-ch | 1499.8<br>16 sub-ch | 2812<br>30 sub-ch | 5436.6<br>58 sub-ch |
| 515                    | (21 ch) | 1.126                  | 1.376              | 1.676              | 2.026              | 2.476               | 2.976             | 3.576               |
| 596                    | (35 ch) | 1.026                  | 1.276              | 1.526              | 1.876              | 2.276               | 2.726             | 3.276               |
| 695                    | (51 ch) | 0.976                  | 1.176              | 1.426              | 1.726              | 2.126               | 2.526             | 3.026               |

## Link Budget in NLOS channel (4)

- **Portable CPE -> Fixed and portable CPE, non-adjacent channel**
  - Receiver sensitivity: -91.3 dBm
- **NLOS (Modified Hata Model, Ref. 2.)**
  - Tx antenna height: 0.5 m; Rx antenna height: 30 m

**Table 10 Achievable communication distance (in km)**

| Portable (Upstream)    |         | Antenna Gain= 0 (dBi)  |                    |                    |                    |                     |                   |                     |
|------------------------|---------|------------------------|--------------------|--------------------|--------------------|---------------------|-------------------|---------------------|
| Center Frequency [MHz] |         | Signal Bandwidth [kHz] |                    |                    |                    |                     |                   |                     |
|                        |         | 93.734<br>1 sub-ch     | 187.47<br>2 sub-ch | 374.94<br>4 sub-ch | 749.88<br>8 sub-ch | 1499.8<br>16 sub-ch | 2812<br>30 sub-ch | 5436.6<br>58 sub-ch |
| 515                    | (21 ch) | 0.926                  | 1.126              | 1.376              | 1.626              | 2.026               | 2.376             | 2.876               |
| 596                    | (35 ch) | 0.826                  | 1.026              | 1.276              | 1.526              | 1.876               | 2.226             | 2.676               |
| 695                    | (51 ch) | 0.776                  | 0.926              | 1.176              | 1.426              | 1.726               | 2.076             | 2.476               |

## Link Budget in NLOS channel (5)

- **Portable CPE -> Portable CPE, adjacent channel**
  - Operating only in 21- 51 TV chs
  - Transmit PSD limit : -1.4dBm/100kHz
  - Receiver sensitivity: -91.3 dBm
- **NLOS (Modified Hata Model, Ref. 2.)**
  - Tx antenna height: 0.5 m; Rx antenna height: 30 m

**Table 11 Achievable communication distance (in km)**

| Portable (Upstream)    |         | Antenna Gain= 0 (dBi)  |                    |                    |                    |                     |                   |                     |
|------------------------|---------|------------------------|--------------------|--------------------|--------------------|---------------------|-------------------|---------------------|
| Center Frequency [MHz] |         | Signal Bandwidth [kHz] |                    |                    |                    |                     |                   |                     |
|                        |         | 93.734<br>1 sub-ch     | 187.47<br>2 sub-ch | 374.94<br>4 sub-ch | 749.88<br>8 sub-ch | 1499.8<br>16 sub-ch | 2812<br>30 sub-ch | 5436.6<br>58 sub-ch |
| 515                    | (21 ch) | 0.726                  | 0.876              | 1.026              | 1.276              | 1.526               | 1.826             | 2.226               |
| 596                    | (35 ch) | 0.626                  | 0.776              | 0.976              | 1.176              | 1.426               | 1.726             | 2.076               |
| 695                    | (51 ch) | 0.626                  | 0.726              | 0.876              | 1.076              | 1.326               | 1.576             | 1.926               |

## Discussion

- **Through the link budget calculations the following observations are drawn:**
  - Fixed CPE (outdoor) seems to have enough capability to cover low-rate regional applications, but use of higher number of subchannels is desirable for larger coverage in the case of NLOS channel.
  - Portable CPE (indoor and outdoor) has limited coverage, especially when it operates in adjacent channel of incumbents.

## References

1. **IEEE 802.22-2011, July 2011**
2. **IEEE 802.15-11-0684-09-004m: TG4m Technical Guidance Document, Mar. 2012**
3. **G. Chouinard, WRAN Reference Model, Doc. IEEE802.22-04/0002r18, Oct. 2011**