Analysis on estimated SNR values on a generic cable plant

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Supporters

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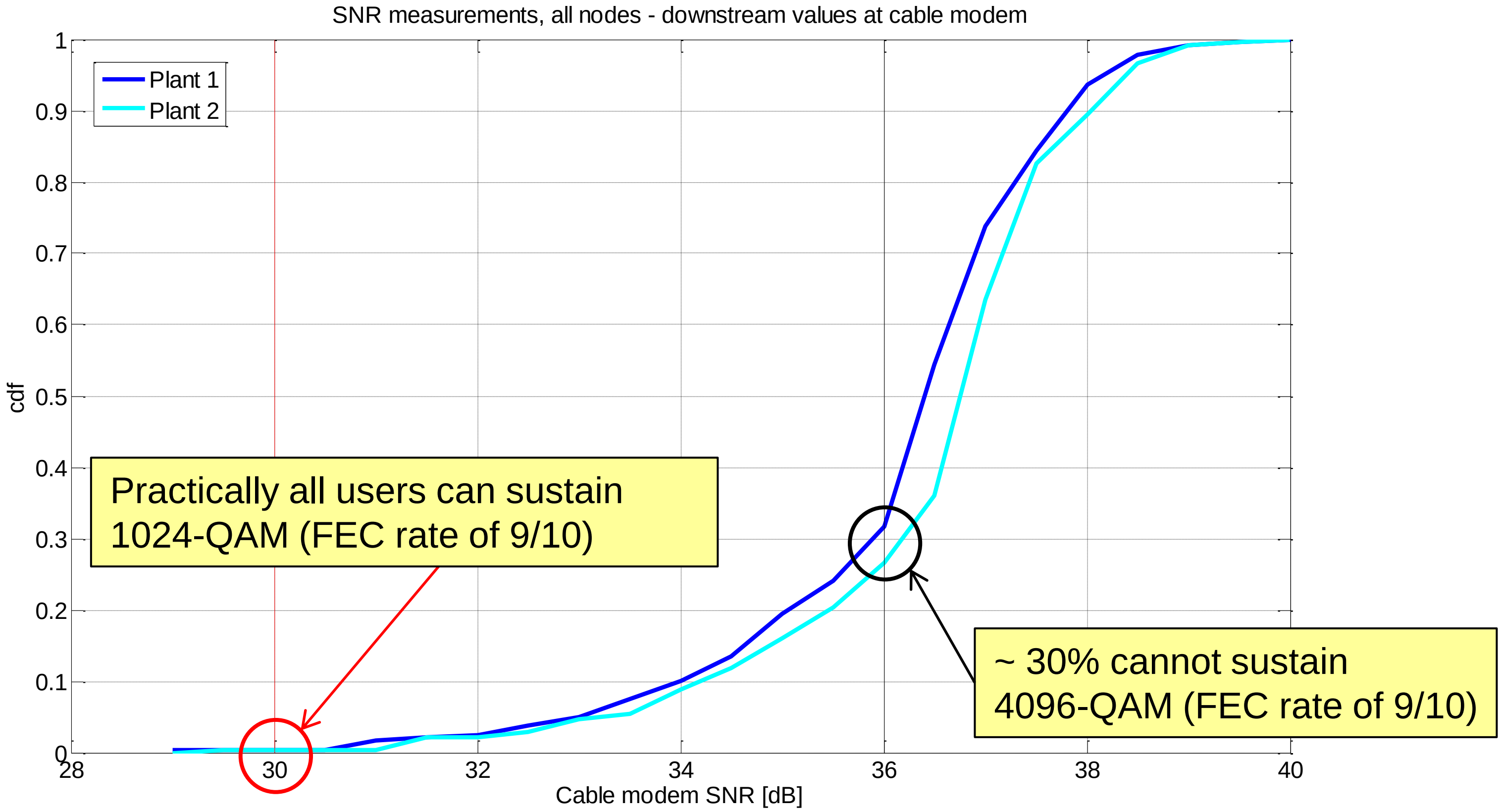
Scope of the presentation

- This presentation illustrates statistics on SNR measurements and SNR estimates on generic cable plants, based on typical architecture and real components characteristics
  - For real plants, SNR are measured at the cable modem below 1 GHz
  - For modeled plants each component is characterized in frequency and modeled accordingly for the analysis between 1.0 and 1.35 GHz and SNR values are estimated based on the plant and components model
- SNR measurements are kindly provided by Comcast
- The model plant structure and characteristics are based upon authors understanding of what a generic EPoC plant will be
- Authors would like to gather feedback and opinion on the presented results

SNR measurements in current used spectrum

- Data from two different plants kindly provided by Comcast are considered for this analysis – each plant has about 240 cable modems
- SNR values are retrieved measurements at the cable modems, for spectrum below 1 GHz – SNR variability over frequency is within 2 dB



SNR measurements – discussion

- Assuming to adapt the modulation and coding scheme to the user SNR:
  - ~70% of the users can have 4096 QAM, FEC rate 9/10
  - ~30% of the users can have 1024 QAM, FEC rate 9/10
  - ➢ Average spectral efficiency is 10.26 bps/Hz when all users are served

- Assuming to serve every user with the same modulation and coding scheme of 1024 QAM and FEC rate 9/10 is the choice:
  - ➢ Average spectral efficiency is 9 bps/Hz and all users are served
    - – Peak data rate is reduced of 20% compared to adapting the modulation and coding

When serving all users and without considering any SNR degradation margin, a **gain of ~14% in spectral efficiency and of 20% in peak data rate** can be achieved by adapting modulation and coding scheme to the user SNR

Cable plant model – a typical scenario

- For spectrum above 1 GHz, no measurements are available and modeling of the plant based on real components characteristics have been done
- A generic passive plant (i.e. N+0) has been considered for the analysis
- The plant includes different cable types, as well as couplers, splitters and tabs, each of them fully characterized in frequency
  - Components are linked together in the cable plant model
  - About 140 subscribers ports are considered in the analysis
  - Thermal noise and micro-reflections have been considered
  - A transmit power level of 65 dBmV have been considered
    - Corresponding to a constant Power Spectral Density of about -69 dBm/Hz
  - Considered spectrum is from 1000 to 1350 MHz, which is a possible candidate of interest for EPoC deployment at high capacity
    - For lower frequency spectrum, the SNR tends to flatten to high values
    - In the upper region instead, components upgrade or other alternatives shall be considered to make a good use of the plant

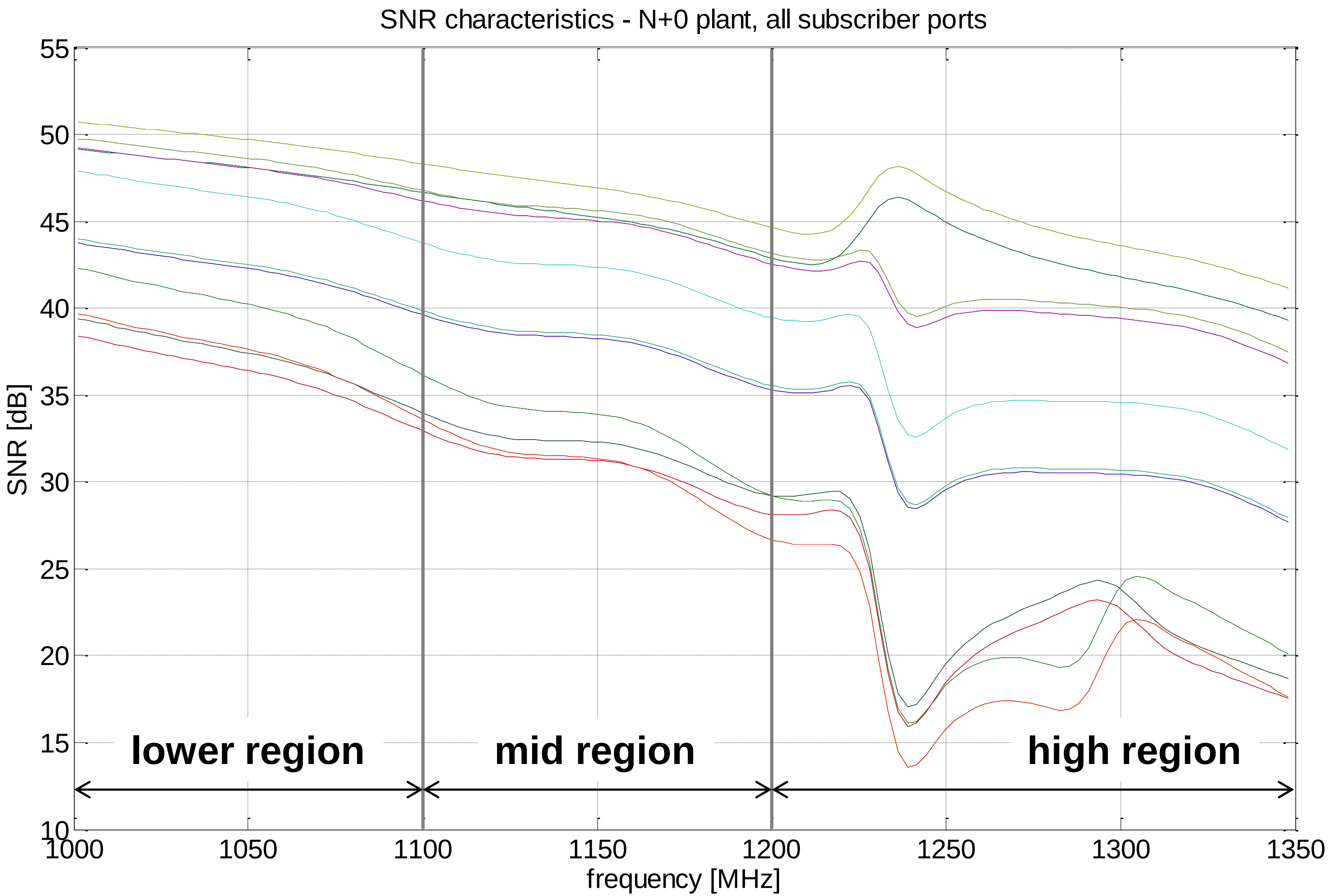
Evaluation method and analysis

- The spectrum has been divided into 128 frequency chunks and for each of the chunk the downstream SNR at the subscriber port has been estimated

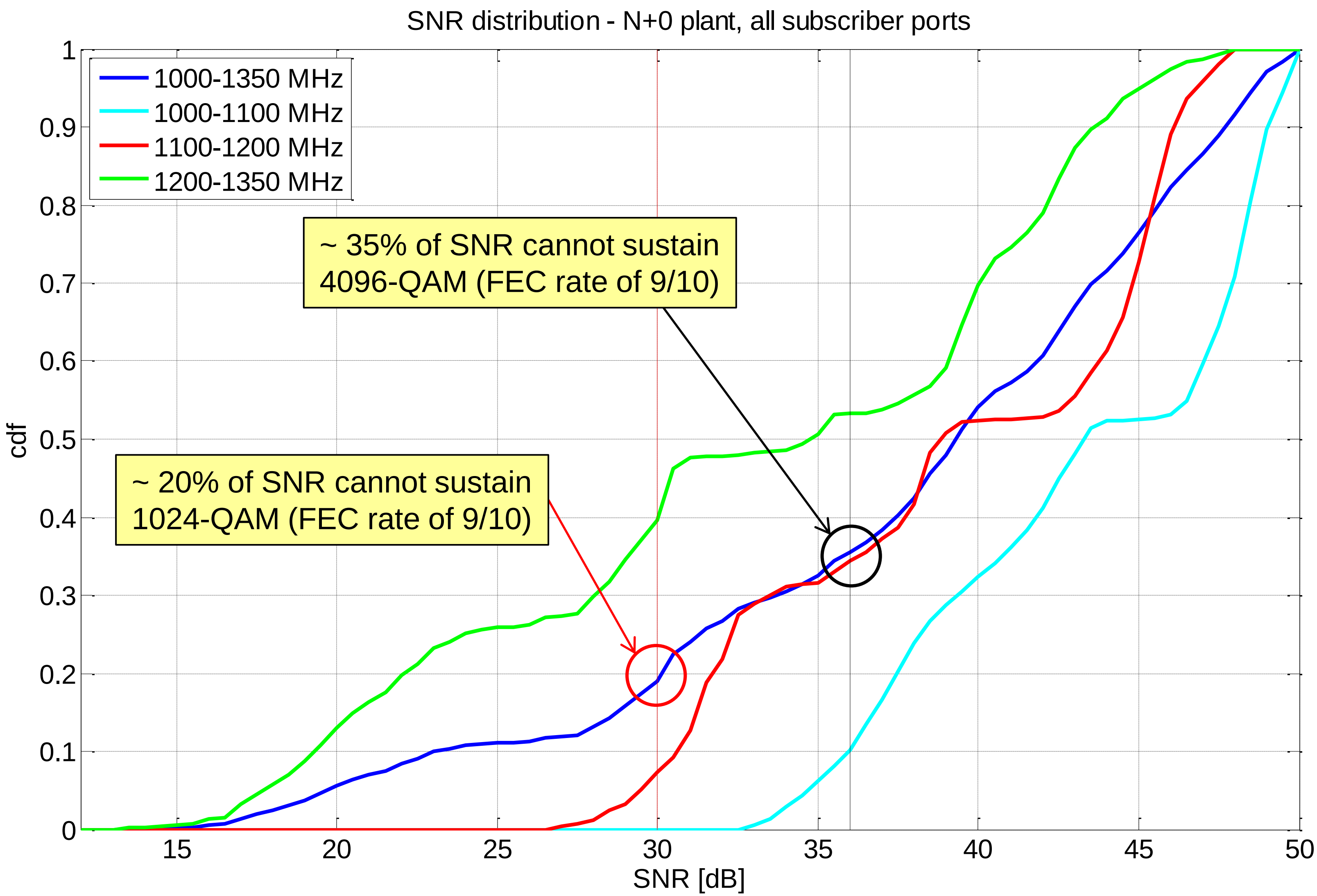
- Statistics of the obtained estimated SNR values have been calculated for the following spectrum regions and represented in terms of CDF
  - 1000 – 1350 MHz – entire spectrum considered (128 chunks)
  - 1000 – 1100 MHz – lower region
  - 1100 – 1200 MHz – mid region
  - 1200 – 1350 MHz – high region

- In addition, average spectral efficiency is derived from estimated SNRs
  - based on Shannon capacity formula, with an SNR upper limit of +36 dB, corresponding at ~12 [bits/s/Hz] of spectral efficiency (before overhead)
  - a penalty of 3.0 dB is included to account for FEC losses
  - the spectral efficiency is averaged over the considered spectrum region

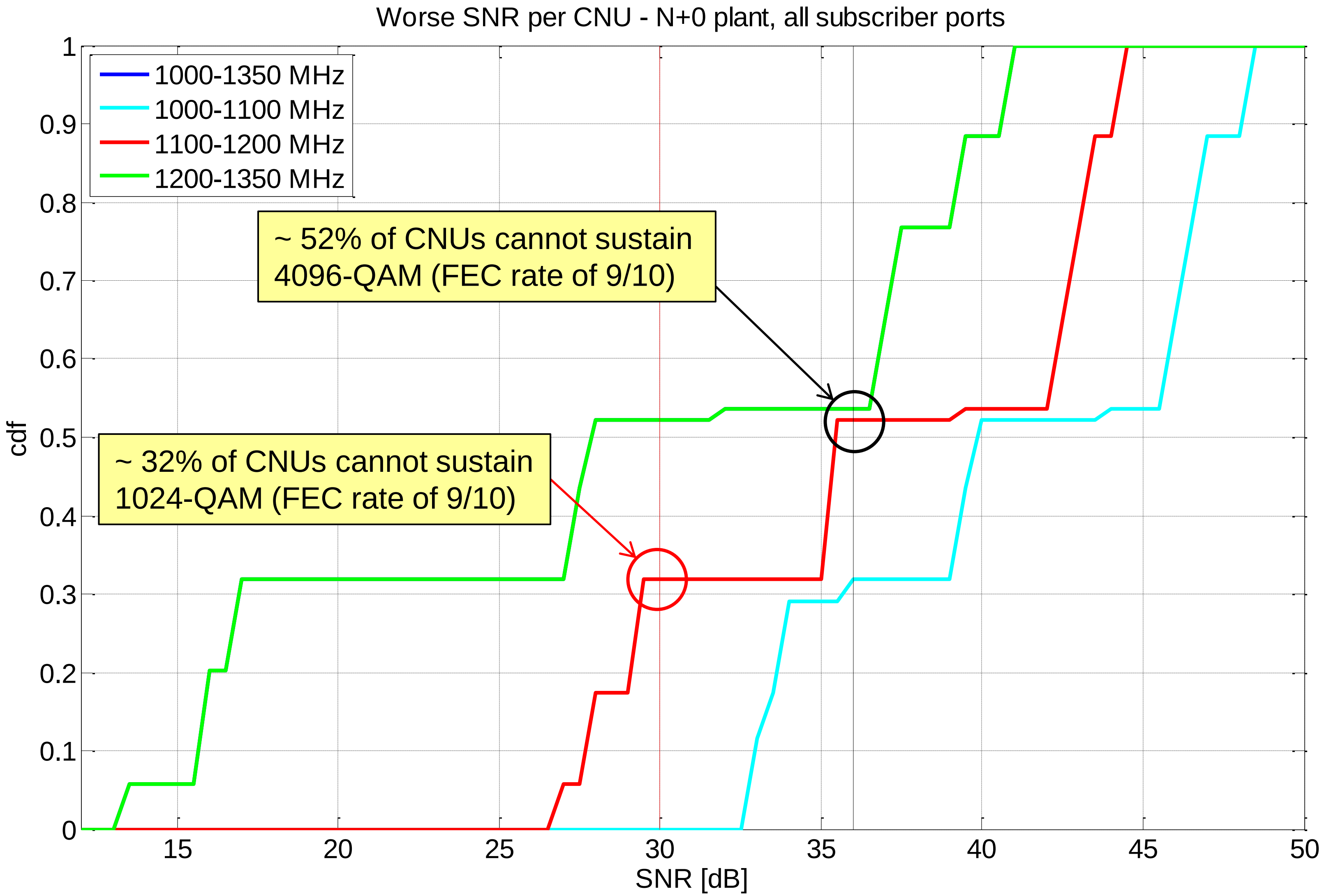
SNR estimates – frequency characteristics



SNR distribution – all values



SNR distribution – worse SNR per CNU



SNR estimates – discussion

- Assuming to adapt the modulation and coding scheme to the user SNR:
  - ~48% of the users can have 4096 QAM, FEC rate 9/10
  - ~20% of the users can have 1024 QAM, FEC rate 9/10
  - ~32% of the users can have 256 QAM, FEC rate 9/10
  - ➢ Average spectral efficiency is 9.3 bps/Hz when all users are served
    - The value would increase to 10.2 bps/Hz if only the lower spectrum region is used

- Assuming to serve every user with the same modulation and coding scheme of 256 QAM and FEC rate 9/10 seems good compromise:
  - ➢ Average spectral efficiency is 7.2 bps/Hz and all users are served – peak data rate is reduced of 50% compared to adaptive case
    - The value would increase to 9 bps/Hz if only the lower spectrum region is used

- When serving all users, a **gain of ~29.2% in spectral efficiency and of 50% in peak data rate** can be achieved by adapting modulation and coding scheme
- In case only the lower region of the spectrum is considered, a **gain of 13.3% in spectral efficiency and of 20% in peak data rate** can be achieved by adaptive modulation and coding schemes

Conclusion

- SNR measurements and SNR estimates distributions are analyzed and translated into achievable spectral efficiency for different scenarios
  - Measured SNR have been collected at cable modems for frequencies below 1 GHz, in several commercial plants
  - Estimated SNR are extracted from N+0 cable plant, modeled above 1 GHz

- Both measurements and estimates show that a **gain of ~15% to 30% in spectral efficiency and of 20% to 50% in peak data rate** can be achieved by adapting the modulation and coding scheme to the actual user SNR, as compared to a fixed scheme
  - SNR variations among users in a plant are present in all frequency regions and they tend to be larger for higher portion of the spectrum
  - Mitigation could be done via plant upgrade to certain extent, but could be costly or not always possible in all locations
  - Alternatively, reduction of service penetration could be considered in some cases

Conclusion (cont.)

- Additional benefits can also be provided by adaptive modulation and coding
  - The system can offer a higher peak data rate to users in good channel conditions
  - The system reliability is increased by adapting to the SNR conditions, as users that may suffer a degradation simply falls back into a lower data rate rather than being disconnected from the system
  - The system can operate at lower margins in case of adaptive SNR as the risk is just for reduced data rate – this also contributes to achieve higher performance

Overall, adaptive modulation and coding scheme is a well promising and flexible option to extract the most from a cable plant, guaranteeing the highest service penetration with small complexity increase, without the need for expensive upgrades

Baseline Proposal

- The PHY shall support adaptive modulation and coding schemes (MCS) to match different channel conditions
  - Adaptation across users shall be possible
  - Adaptation across frequency shall be possible

- Moved by:
- Seconded by:
- Technical motion (>=75%)
- Yes / No / Abstain

Note: Each MCS is defined by a particular modulation order and a coding rate