**IEEE P802.15**

**Wireless Personal Area Networks**

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| Abstract | Information on the ULP TASK PHY proposal of TG4q |
| Purpose | To summarize the unique features and benefits of ULP TASK part of TG4q PHY proposal. |
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# Definitions

* *Ternary spreading code:* An L-length, $Q$$Q$-element ternary spreading code*,* $C\left(L, Q\right),$$C\left(L,Q\right),$ is defined as the set of *M* spreading sequences, each having *L* chips, whose chip-values belong to the ternary alphabet $\left\{-1, 0, 1\right\}$.
* *M/L-TASK modulation:* M/L-TASK modulation is a mapping of data-symbols from a $Q$$Q$-ary ($Q=2^{M})$$Q=2^{M})$) alphabet on to the ternary spreading code $ C\left(L, Q\right)$$C\left(L,Q\right)$.
* *Cross-correlation functions:* For any two L-length sequences, $x=\left[x\left[0\right], …, x\left[L-1\right]\right]$$x=\left[x\left[0\right],…,x\left[L-1\right]\right]$and $y=\left[y\left[0\right],…, y\left[L-1\right]\right], $$y=\left[y\left[0\right],…,y\left[L-1\right]\right],$*.*

Cross-correlation in coherent mode,$R\_{coh}\left(x,y\right)$$R\_{coh}\left(x,y\right)$, is defined as

$$R\_{coh}\left(x,y\right)=\sum\_{l=0}^{L-1}x\left[l\right]y[l]$$

Cross-correlation function in non-coherent mode,$R\_{non-coh}\left(x,y\right)$$R\_{non-coh}\left(x,y\right)$, is defined as

$$R\_{non-coh}\left(x,y\right)=\sum\_{l=0}^{L-1}\left|x\left[l\right]\right|\left|y\left[l\right]\right|$$

# Features of ULP-TASK modulation

* Use of simple amplitude shift keying modulation
* Use of ternary spreading codes with special properties
* Data-symbols are spread using sequences whose chip values are taken from the set {-1, 0, 1}. The sequences of the spreading codes are designed to ensure that they exhibit excellent correlation properties in both coherent and non-coherent modes. Since cross-correlation properties of the spreading code essentially determine the performance of the TASK, the transmitted data can be reliably decoded at both coherent and non-coherent receivers. Further, and notably, the performance of the employed ternary spreading codes in the coherent and non-coherent modes is close to the best known spreading codes in the respective modes (i.e., Walsh-Hadamard (W-H) codes in coherent mode and optical orthogonal codes (OOC) in non-coherent mode).
* Duty cycling at data-symbol level
* Due to the balanced property of the spreading sequences, the TASK modulated waveform has duty cycling within each data-symbol with an approximate ratio of 0.5.

# Benefits of ULP-TASK modulation

## Support for both coherent and non-coherent modes of reception

The benefits of supporting both coherent and non-coherent modes of reception can be understood with the help of Figure A. 1. In Figure A. 1, the variation in the transmitter power ($ P\_{T}$) is plotted with respect to the communication range$ (d)$, for different path-loss models. Since$ P\_{T} ∝d^{α}$, it can be seen that the required transmitter power increases polynomial with respect to distance. Importantly, for short communication range ($d\leq 15 m$), the required transmit power is small and has minimal variations. Hence, within this range, the focus should be more on optimizing the receiver power consumption. Therefore, it would be beneficial to have an ultra-low power receiver in this range, and such a requirement can be met by employing non-coherent reception mode. Beyond $d=15 m,$ for a fixed communication range, the transmitter power consumption can be traded off with the receiver performance. This can be achieved by judiciously choosing either a non-coherent receiver or a coherent receiver depending on the application scenarios. In summary, the capability of simultaneously supporting coherent and non-coherent reception efficiently achieves trade-off between the receiver performance, power consumption and the communication range.



**Figure A. 1— Variation of the required transmitter power with the communication range**

## Spreading with variable spreading factors to enable scalable data rates

Spreading with variable spreading factors enables a balanced trade-off between bandwidth expansion (hence the data rate) and reliability. This feature can be leveraged at the MAC layer level to design efficient scheduling protocols based on the metrics such as LQI.

## Ultra-low power transceiver implementation

The presence of simple ASK mechanism significantly simplifies the transceiver design. It also enables the use of non-coherent receivers, relaxes requirements on carrier frequency parameters, thereby enabling simpler and ultra-low power receiver implementations .such as super regenerative receivers (SRR), etc. Further, the inherent duty-cycling of TASK reduces power consumption at the transmitter.