Explicit asymptotic secret key rate of continuous-variable QKD with an arbitrary modulation

Aurélie Denys, Peter Brown, Anthony Leverrier

Explicit asymptotic secret key rate of continuous-variable QKD with an arbitrary modulation

Quantum 5, 540 (2021)

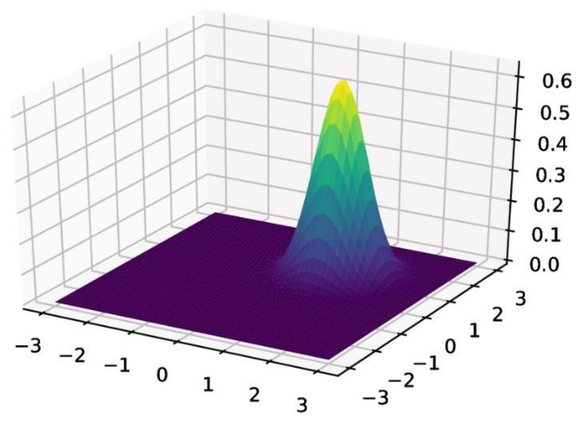
Aurélie Denys[1], Peter Brown[2], Anthony Leverrier[1]
1. Inria Paris, France 2. ENS de Lyon, France

CONTINUOUS VARIABLE QKD PROTOCOL

Quantum part (repeated):

1. Alice randomly chooses one coherent state $|\alpha_k\rangle$ with probability p_k from a set of coherent states $\{|\alpha_k\rangle\}_{k\in I}$ and sends it to Bob.
2. Bob measures the quadratures of the states he receives, using coherent detection, and obtains β_k.

+ Classical post-processing



Wigner function of the coherent state $|\alpha\rangle$, with $\alpha = 1 + i$

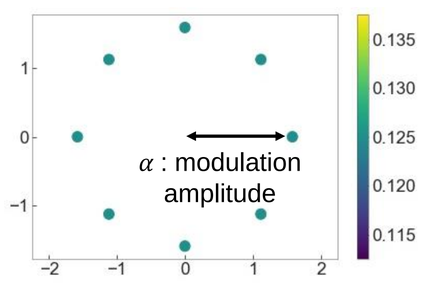
SECURITY PROOF

- Security proof in the asymptotic regime, under the restriction to collective attacks

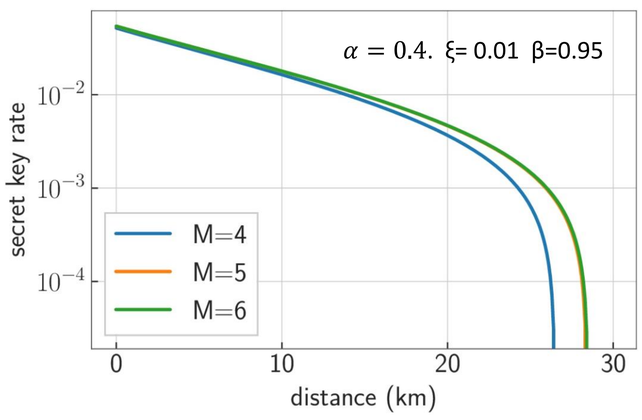
- Main steps:
  - Devetak-Winter bound : bound on the asymptotic secret key rate
$$\mathrm{k} = I(X;Y) - \sup_{N:A'\to B} \chi(Y;E)$$
  - Function of a covariance matrix :
$$\sup_{N:A'\to B} \chi(Y;E) \leq \mathrm{f}(\Gamma) \qquad \text{where } \Gamma = \begin{bmatrix} V\, I_2 & Z\, \hat{\sigma}_z \\ Z\, \hat{\sigma}_z & W\, I_2 \end{bmatrix}$$
  - Z cannot be measured directly in the prepare & measure protocol
  ⇒ we write it as a Semidefinite Program (SDP)
  - Bound on its solution: $\mathrm{Z} \geq \mathrm{Z}^* \coloneqq 2\, c_1 - 2\left(\left(n_B - \frac{c_2^2}{\langle n \rangle}\right) w\right)^{1/2}$ (*)

OPTIMAL CONSTELLATIONS?

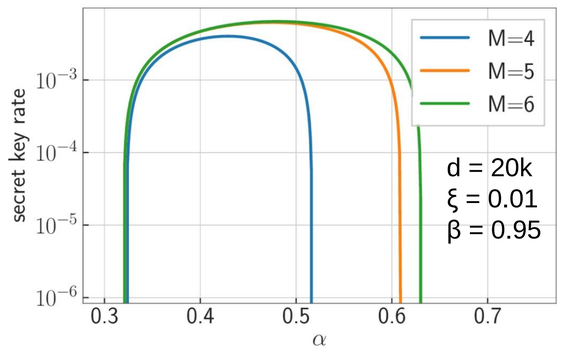
Phase-shift keying modulations



8-PSK constellation

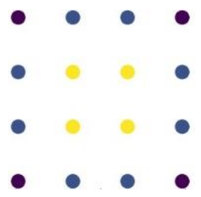


Asymptotic secret key rate as a fonction of the distance for the M-PSK modulation schemes.



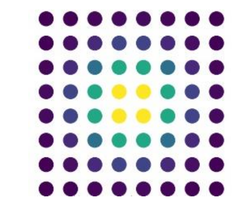
Asymptotic secret key rate as a fonction of the modulation amplitude for the M-PSK modulation schemes.

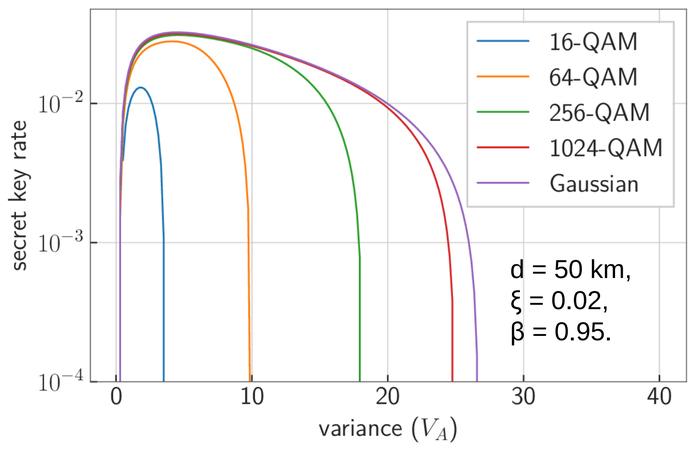
Quadrature amplitude modulations (QAM)



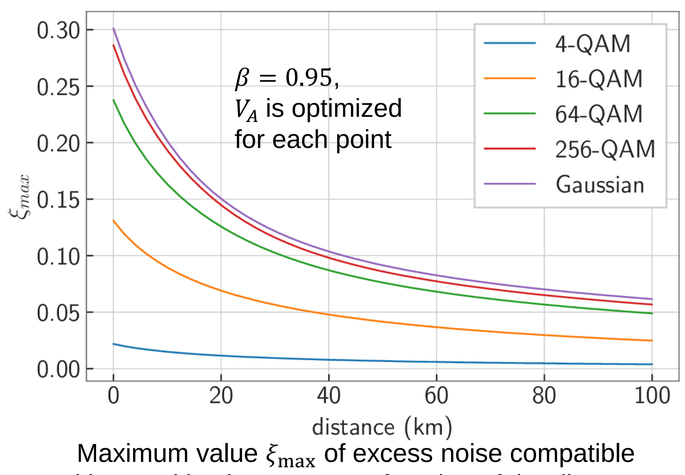
Before our work, only simple modulations (Gaussian modulation, quadrature phase-shift keying [1,2], etc.) could be analysed. The analytical formula (*) now makes possible the study of more relevant discrete modulations, such as the QAM.

[1] Ghorai et al., Phys. Rev. X, 9, 2, 021059, (2019)
[2] Lin et al., Phys. Rev. X, 9, 4, 041064, (2019)

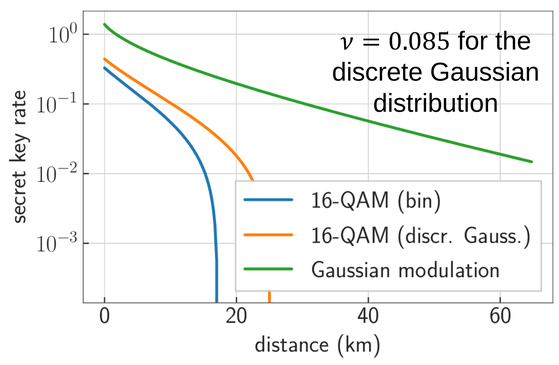


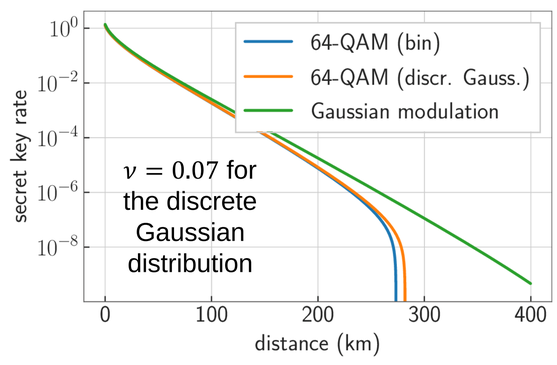


Secret key as a function of the modulation variance V_A, for various modulation schemes (with binomial distribution).



Maximum value $\xi_{\max}$ of excess noise compatible with a positive key rate as a function of the distance, for various QAM sizes (with binomial distribution).





Bound on the asymptotic secret key rate as a function of the distance.
Fixed parameters : V_A = 5, ξ = 0.02, β = 0.95

Parameters: d: distance between Alice and Bob, V_A: modulation variance, ξ: excess noise, β: reconciliation efficiency, ν: parameter for the discretised Gaussian distribution.

“Relatively small constellation sizes, with say 64 states, are essentially sufficient to obtain a performance close to a true Gaussian modulation”