CoRINA : Communication par Relais Intermediaires Navals Autonomes

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Overview

Autonomous seafloor mapping

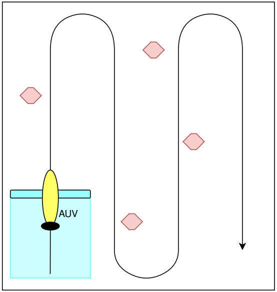


Figure: Autonomous target seeking

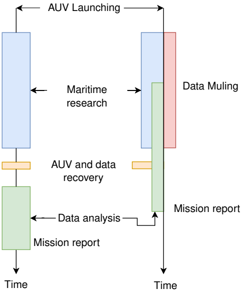
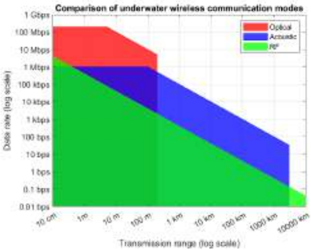


Figure: Seeking time line

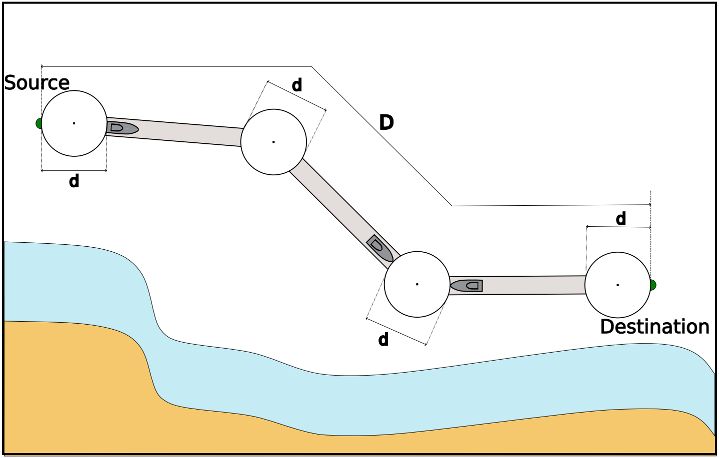
Empirical Range–Data-Rate Relationships for underwater wireless interfaces [FvTS20]



Empirical Range–Data-Rate Relationships for underwater wireless interfaces [Fewell et al., 2020]

Wave type	Data rate × Range	Range	300 m	300m 1GB
Acoustic	100 kb/s × km	1000 km	300 kb/s	7.4 h
RF	0.4 kb/s × km	10 m	1.2 kb/s	/
Optic	1000 Mb/s × m	100 m	300 Mb/s	26 s

A data muling example



Definition

Data Muling

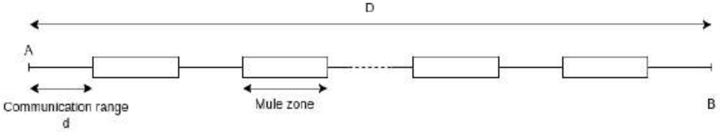
Use of a mobile agent, called mule, to physically transport data [Shah et al., 2003]

Example (Mailman)

For example the Post system. The Mailman is the "mule" by carrying data, a mail, from the Post office to the mailbox

Characteristic of a mule

- Short range communication system (high bandwidth)
- Capacity to reach the communication zone



Transfer time

Time to transmit P batches of m bits from A to B whit N mules:

$$T_{latency} = (N+1) \times (T_{com} + T_{rdv}) + N \times T_{travel}$$

$$T_{total} = T_{latency} + (P-1)(2 \times (T_{com} + T_{rdv}) + 2 \times T_{travel})$$

$$T_{com} = \frac{m}{B_{sr}} + \frac{d_{sr}}{c_{sr}} \qquad T_{travel} = \frac{D-(N+1)d_{sr}}{Nv_{mule}}$$

Apparent Datarate

$$R_{eq} = \frac{P \times m}{T_{Total}} \quad (1)$$

Latency Analysis

By expending and factorising the latency equation :

$$T_{latency} = \frac{D}{v_{mule}} + (N+1)\left(\frac{m}{B_{sr}} + \frac{d_{sr}}{c_{sr}} - \frac{d_{sr}}{v_{mule}} + T_{rdv}\right)$$

And so, a criteria to lower $T_{latency}$:

$$\begin{cases} \frac{m}{B_{sr}} + \frac{d_{sr}}{c_{sr}} - \frac{d_{sr}}{v_{mule}} + T_{rdv} > 0 => Lower\ mule\ number \\ \frac{m}{B_{sr}} + \frac{d_{sr}}{c_{sr}} - \frac{d_{sr}}{v_{mule}} + T_{rdv} < 0 => Higher\ mule\ number \end{cases}$$

Simulation

Hypothesis:

- Perfect navigation
- underwater optical communication system

Parameters	Value
D	300 m
R	27.1 Mbps
d	10 m
T_{rdv}	0 s (green) 100 s (blue)

(With a point to point acoustic link : 300 kb/s)

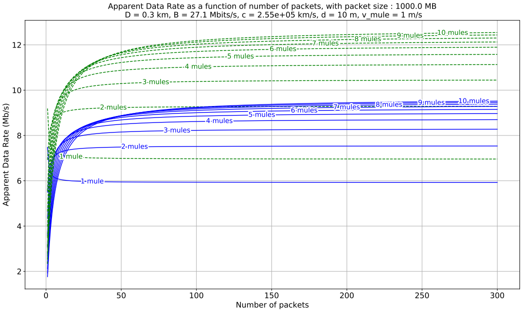
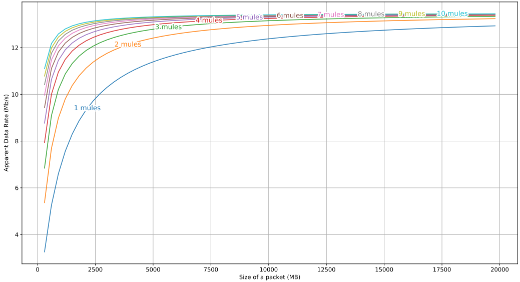
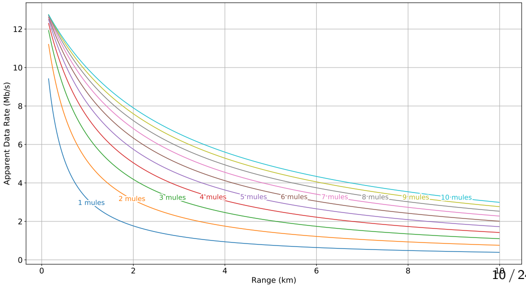


Figure: Evolution of the apparent data rate with respect to the size of one packet

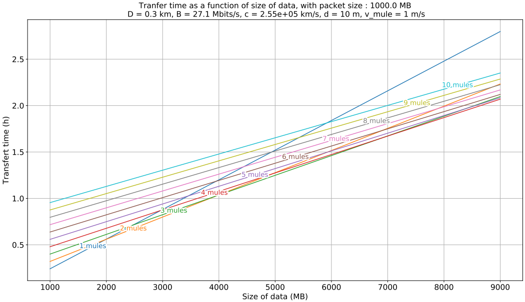
Parameters	Value
D	300 m
R	27.1 Mbps
d	10 m
T_{rdv}	0 s





Transfer time vs data size

Parameters	Value
D	300 m
R	27.1 Mbps
d	10 m
T_{rdv}	0 s



Scenario

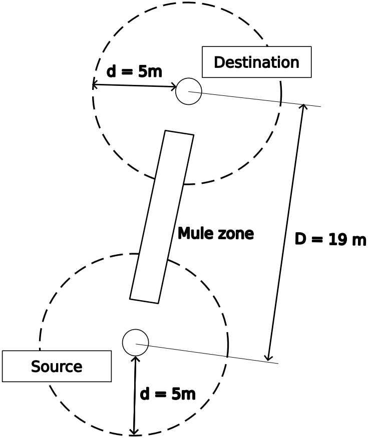


Figure: Scenario

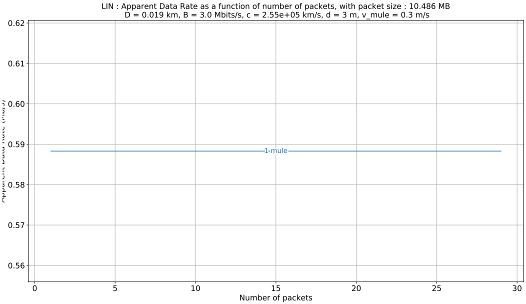


Figure: Estimation

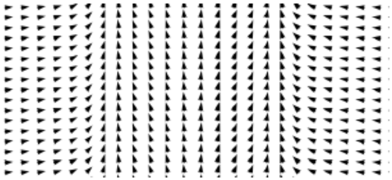
Experimental platform

Specifications :

- differential drive
- IMU and GPS fusion for position and velocity estimation
- 2.4 GHz wifi

Behavior

- Vector field navigation



- Zone definition ? Cartesian points from GPS projection
- Communication range : 5 m, data rate : 3 Mb/s
- Mule speed : 0.3 m/s

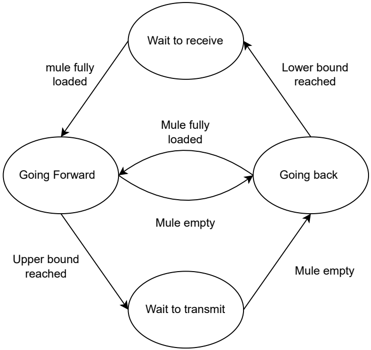


Figure: State machine of a mule

Results

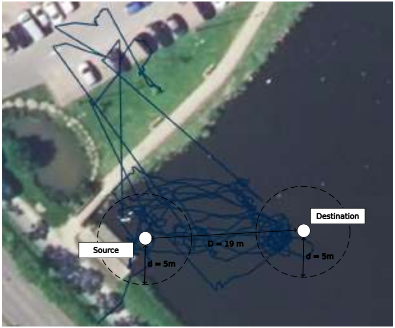


Figure: GPS trace of the mule

Apparent data rate : 0.09 MB/s with 6 transmitted packets in 669 s

Conclusion

The linear data muling allows on paper:

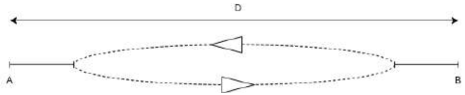
- to significantly extend the range of a network
- to extend data rate
- can have application on underwater, surface or terrestrial field

With a criteria to :

- choose mule number
- switch concept to circular muling system [Fewell et al., 2020]

But to be operational, it leaves significant technical issues that need to be address :

- Reliable Rendezvous
- Energy consideration
- Launch and recover this system



Question Time

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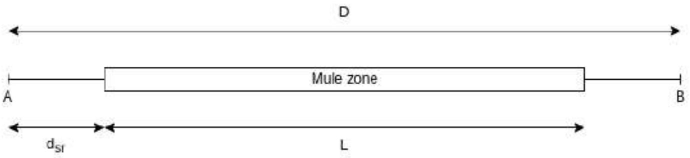
The 1-mule system

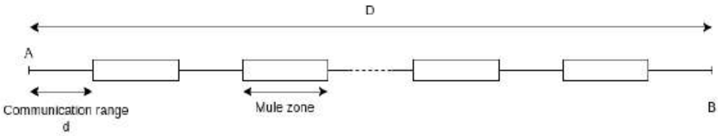


Communication of m bits from A to B, spaced by a distance D.
Mule characteristic sizes :

- d_{sr} : range of the short-range communication system
- B_{sr} : data rate of the short-range communication system
- c_{sr} : celerity of the canal used for the communication
- v_{mule} : moving speed

$$T_{com} = \frac{m}{B_{sr}} + \frac{d_{sr}}{c_{sr}} \qquad T_{travel} = \frac{L}{v_{mule}} = \frac{D - 2 \times d_{sr}}{v_{mule}} \tag{2}$$

Linear N-mules system



Latency expression

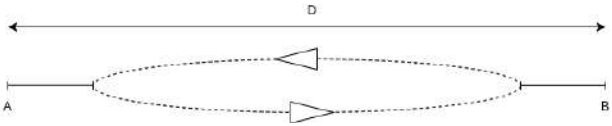
Time to transmit a batch of *m* bits from A to B whit N mules:

$$T_{latency} = (N+1) \times (T_{com} + T_{rdv}) + N \times T_{travel} \tag{3}$$

With :

$$T_{com} = \frac{m}{B_{sr}} + \frac{d_{sr}}{c_{sr}} \qquad T_{travel} = \frac{D - (N+1)d_{sr}}{N v_{mule}}$$

Circular N-mules system



circular muling [Teixeira et al., 2019]

Time to transmit a batch of M data from A to B with N mules:

$$T_{batch} = 2 \times T_{docking} + 2 \times T_{travel} + (N+1) \times (2T_{docking} + \frac{T_{com}}{N}) \quad (4)$$

With :

$$T_{com} = \frac{M}{B_{sr}} + \frac{d_{sr}}{c_{sr}} \qquad T_{travel} = \frac{D - 2d_{sr}}{v_{mule}}$$