rQUIC
Another QUIC + FEC approach

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What is rQUIC?

- FEC prevents retransmissions, enabling robust and low latency communications.
- At the beginning of QUIC there was an unsuccessful intent to implement FEC.
- Recently F. Michel et al. have developed and presented a QUIC + FEC implementation.

Presented at IFIP 2019

- In parallel, there was another QUIC + FEC development, led by Pablo Garrido, with a different approach, and different results.

rQUIC

Presented at IFIP 2019

To be presented at GLOBECOM 2019

https://github.com/pgOrtiz90/quic-go-fec

- Which QUIC + FEC is better and in which cases? Is it worth merging?

Coding after encryption?

As stated in ‘Coding for QUIC’ document:

> **3.3. FEC Protection Within an Encrypted Channel**
>
> FEC encoding is applied before any QUIC encryption and authentication processing. Source symbols, that constitute the data units used by the FEC codec, contain cleartext data (application and/or QUIC data).

https://tools.ietf.org/html/draft-swett-nwcrg-coding-for-quic-03#section-3.3

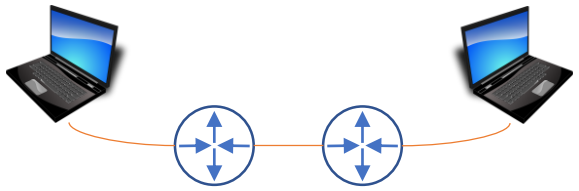
Work on rQUIC started as addition of FEC to QUIC in the most practical and efficient possible manner.
The focus was the resulting implementation. Therefore, no ID was consulted prior to this work.

Encoding after encryption was chosen for two main reasons:

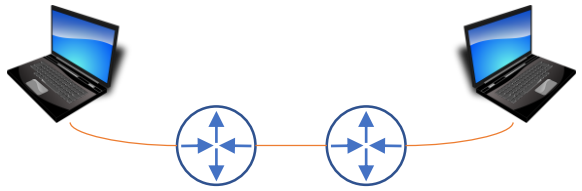
1) Easier implementation
2) Easier scaling to QUIC-NC

NC = Network Coding

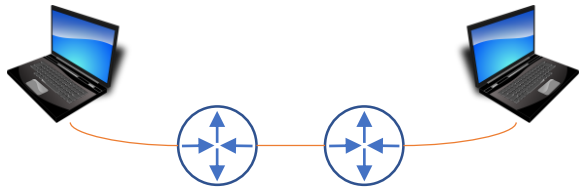
Network Coding and encryption



QUIC connection			
	QUIC connection		
		QUIC connection	
Encode			
Encrypt			
Send	Receive		
	Decrypt		
	Recode		
	Encrypt		
	Send	Receive	
		Decrypt	
		Recode	
		Encrypt	
		Send	Receive
			Decrypt
			Decode



QUIC connection			
Encode			
Encrypt			
Send	Receive		
	Hack		
	encryption		
	(if you can)		
	Decrypt		
	Recode		
	Encrypt		
	Send	Receive	
		Hack	
		encryption	
		(if you can)	
		Decrypt	
		Recode	
		Encrypt	
		Send	Receive
			Decrypt
			Decode

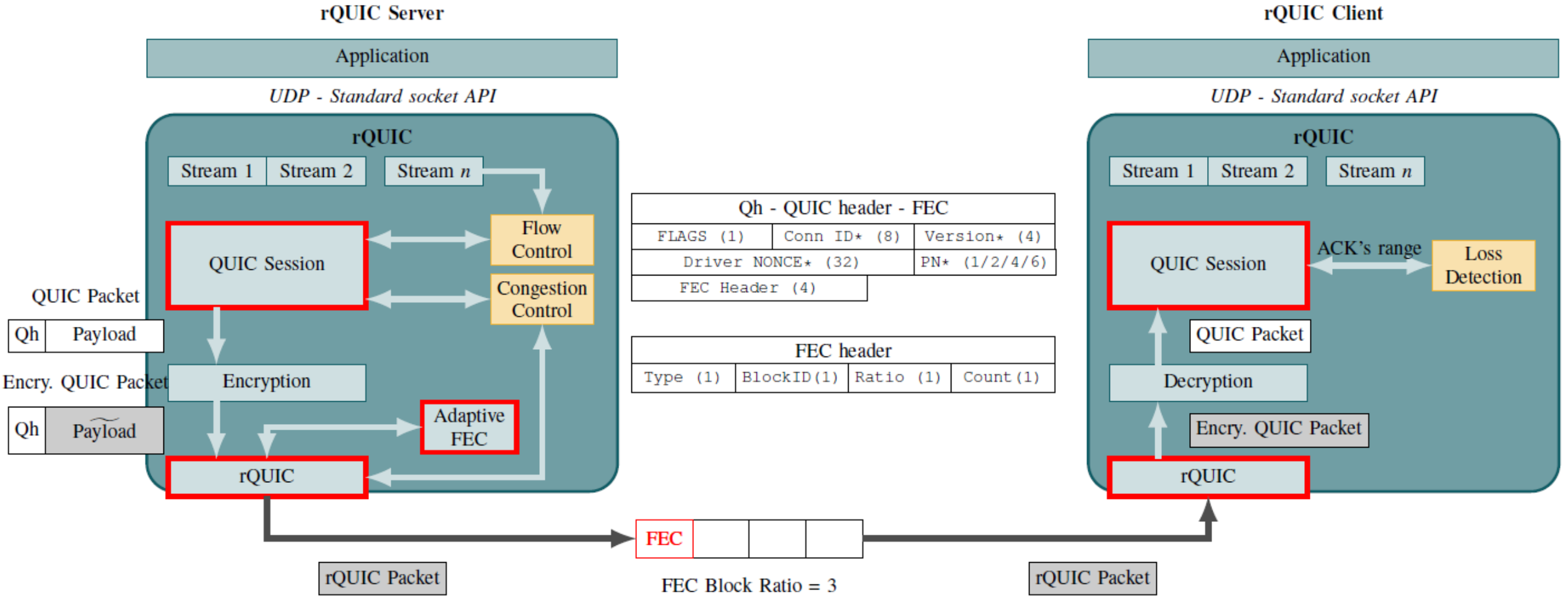


QUIC connection			
Encrypt			
Encode			
Send	Receive		
	Recode		
	Send	Receive	
		Recode	
		Send	Receive
			Decode
			Decrypt

Implementation

- rQUIC is based on quic-go (https://github.com/lucas-clemente/quic-go). The base code was taken after v0.7.0 release.
- Rather than testing all existing coding schemes, the work focused on coding strategy implementation, only using XOR to code.
- In NC terms, generation sizes of *n* are protected by 1 coded packet. Coding rate is adaptive.
- 4 bytes long FEC header is added with the following fields:
  - Type: protected, unprotected and coded.
  - BlockID: in NC terms, generation ID.
  - Ratio: generation size.
  - Count: packet order in FEC block (generation).

Implementation overview



Red borders show new or modified QUIC blocks.

Adaptive coding rate

Adaptive coding rate reduces overhead in the absence of losses.

The algorithm is based on steering *residual losses*, which are packets that need to be retransmitted due to FEC failing to recover.

Given the period i of length T, the residual loss is computed as:

$$\epsilon_i = \frac{retransmissions}{transmissoins - retransmisions}$$

The residual losses are then averaged over N periods:

$$\bar{\epsilon} = \frac{1}{N}\sum_{i=1}^{N}\epsilon_i$$

The algorithm:

if $\bar{\epsilon} < \gamma$ **then**

$$r = r \cdot (1 - \delta)$$

else

$$r = r \cdot (1 + \delta)$$

end if

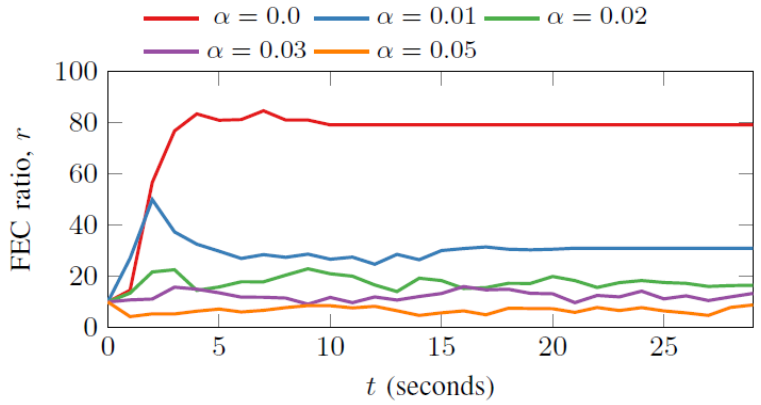
δ and γ can be seen as aggressiveness parameters of the algorithm.

δ and γ are configurable and determine the tolerance to FEC recovery failure.

After analysis of the behavior under different network topologies, we choose

$$T = 3 \cdot RTT \qquad \delta = 0.33 \qquad \gamma = 1\%$$

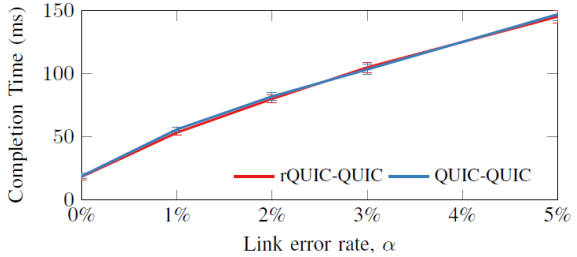
Evolution of rQUIC's adaptive FEC ratio over time, for different link loss rates with 0 (no loss), 1, 2, 3 and 5%.



Evaluation

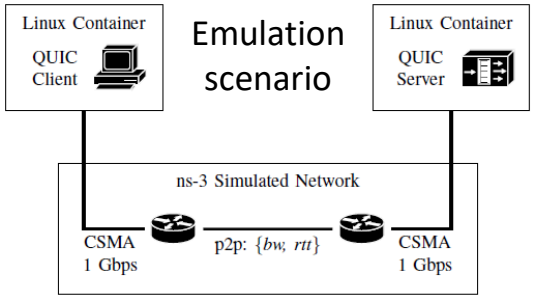
rQUIC fairness check

QUIC session coexisting with (1) rQUIC session and (2) another QUIC session (25ms, 20 Mbps).



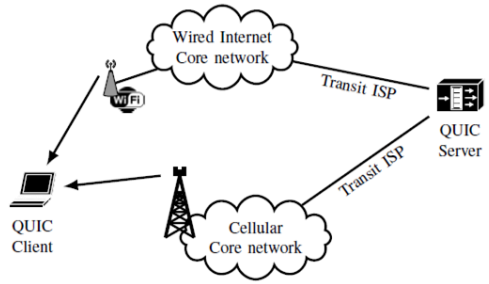
rQUIC does not impair QUIC

SIMULATIONS



PHYSICAL SETUP

(provided by Simula)



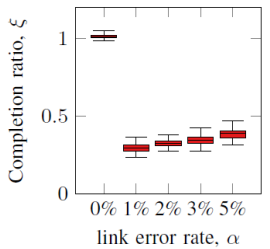
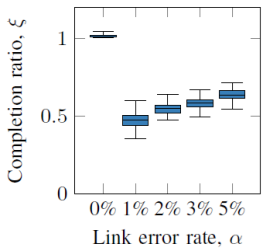
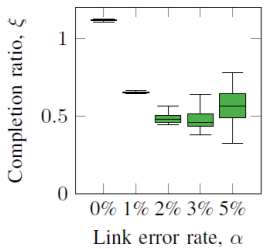
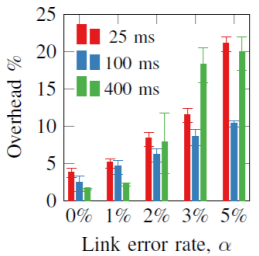
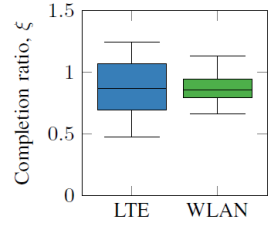
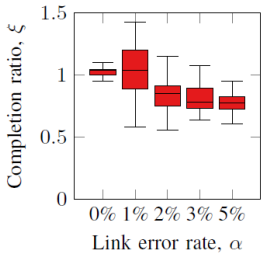
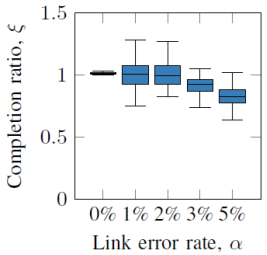
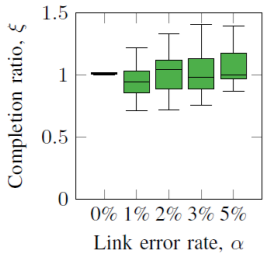
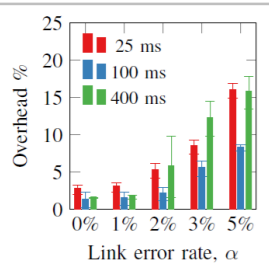
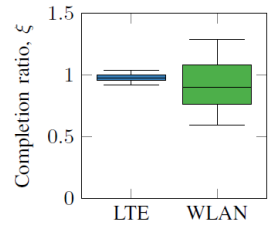
Measured output:

Completion ratio

$$\xi = \frac{Completion\ Time\ rQUIC}{Completion\ Time\ QUIC}$$

Overhead

$$Overhead = \frac{FEC\ packets}{Total\ packets}$$

	25 ms, 20 Mbps (WiFi/LTE)	100 ms, 10 Mbps (2G/3G)	400 ms, 1.5 Mbps (Satellite)	Overhead	Physical setup
Bulk Transfer (20 MB for WiFi/LTE and 2G/3G, 5 MB for satellite)					
HTTP/2 transfer (fickr.com) (30 objects, 1.776 KiB)					

Summary

- rQUIC is another modification of QUIC with FEC, different from the known one (by F. Michel).
- Although tested with only 1 coding scheme, it significantly improves bulk transfer traffic.
- Transparent design (to QUIC) which eases new coding schemes integration.
- With this implementation it is easier to give the next step:
  QUIC with Network Coding.
- Upcoming features:
  - More coding schemes (‘light-weightest’ first)
  - Base code update (inclusion of new quic-go features)
  - Current code improvements (such as adaptation in slow start phase and out of order packets management)
  - Multipath
  - Network Coding

Thank you

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