ETH zürich

PURE:
Payments with UWB RElay-protection

D. Coppola

G. Camurati

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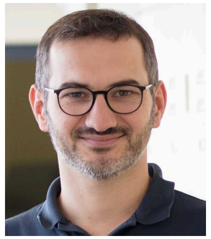
P. Schaller

D. Basin


S. Capkun

Relay Attacks on Contactless Payments

* A Practical Relay Attack on ISO 14443 Proximity Cards, G.Hancke

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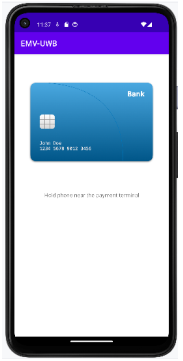

Hold phone near the payment terminal

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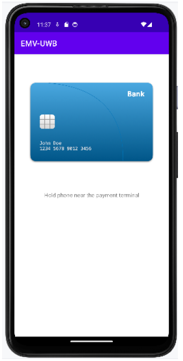

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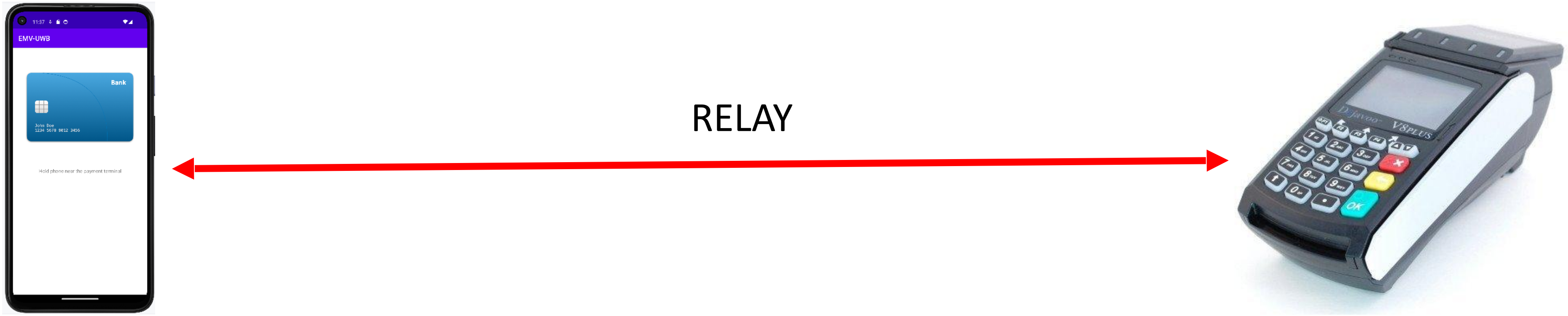

EMV-UWB

Bank

John Doe
1234 5678 9012 3456

Hold phone near the payment terminal

RELAY

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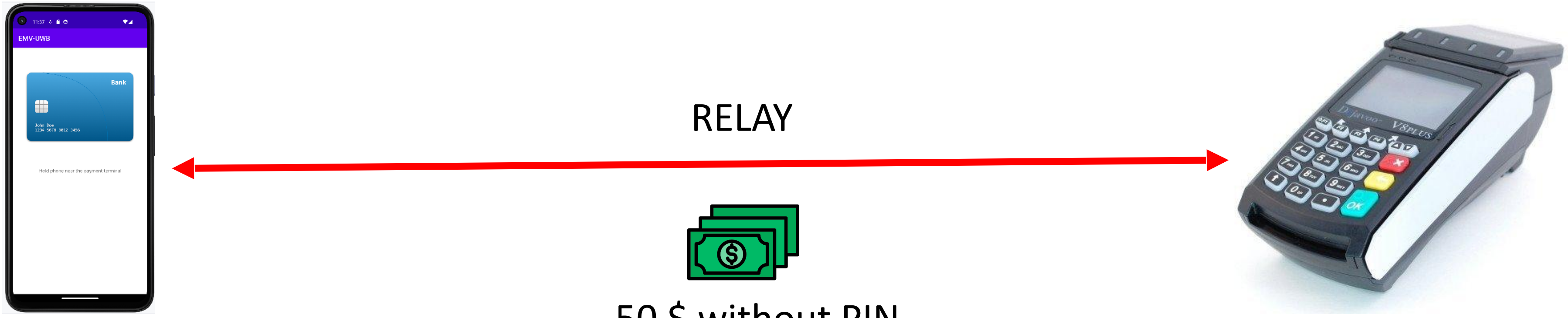

RELAY

~50 $ without PIN
Up to card limit with an unlocked phone

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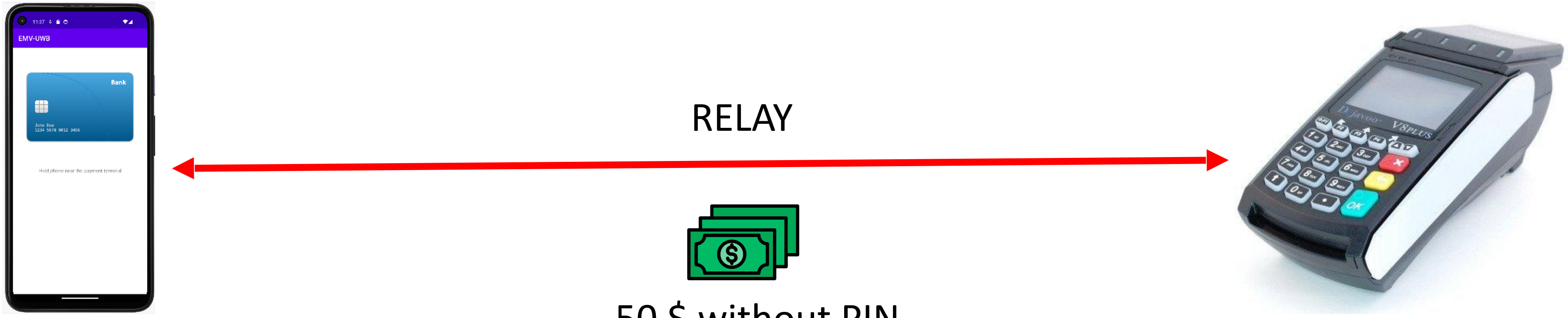

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Logical layer relays

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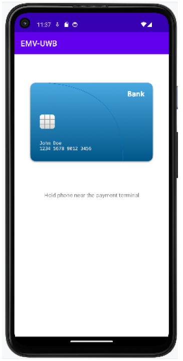

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EMV-UWB

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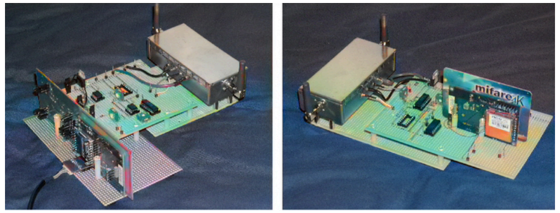

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Physical layer relays

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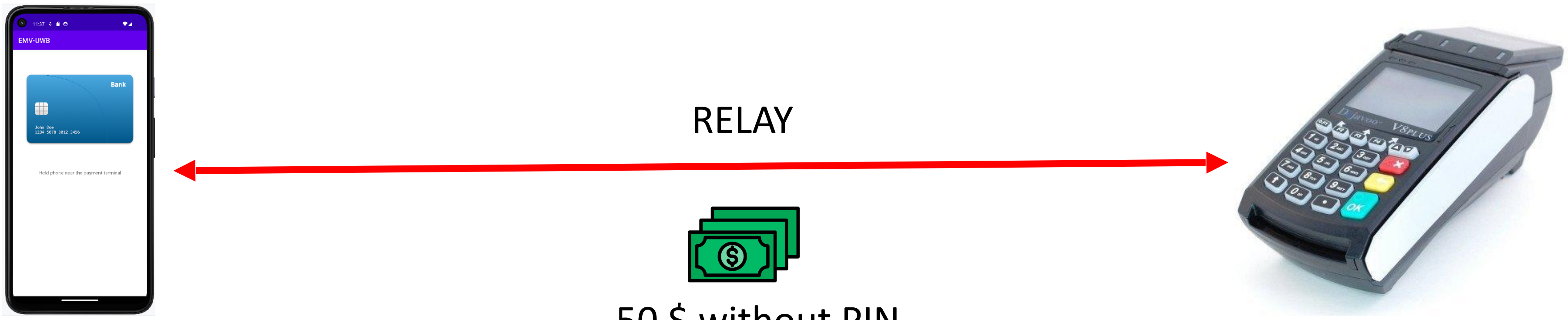

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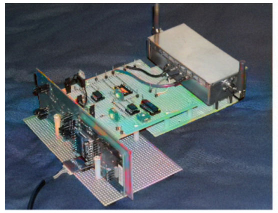

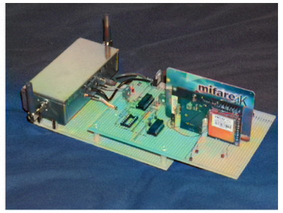

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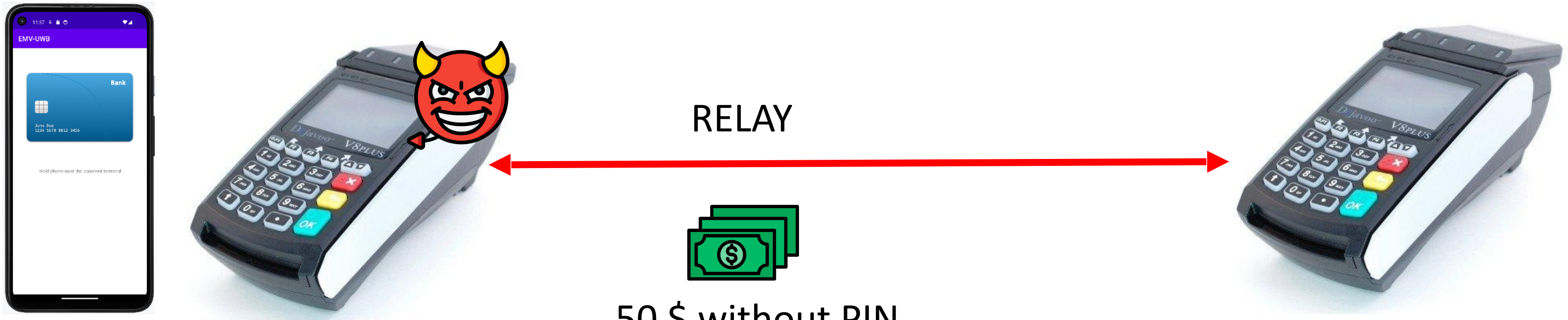
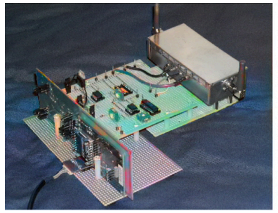


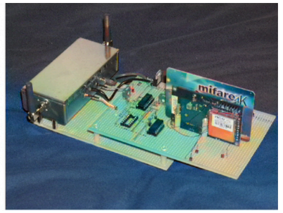
RELAY

Fake terminal

~50 $ without PIN
Up to card limit with an unlocked phone

Logical layer relays





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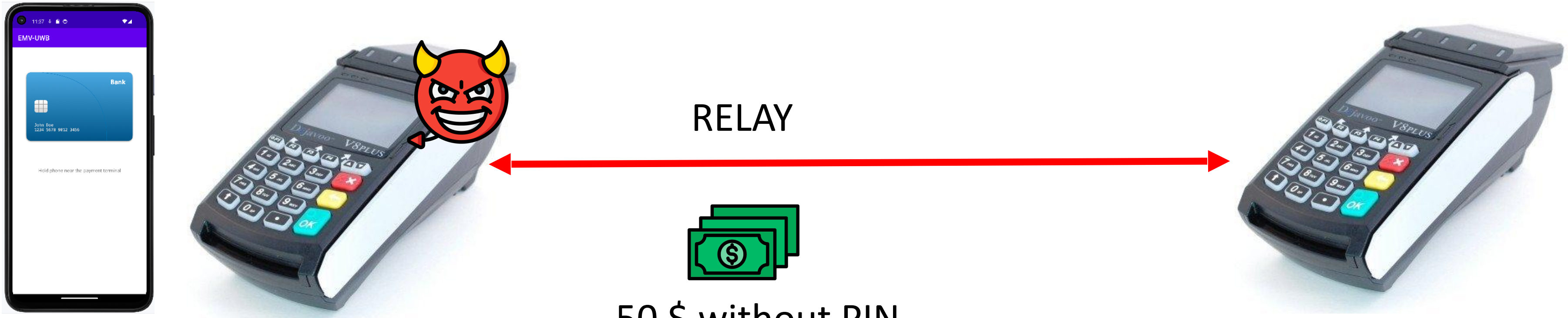
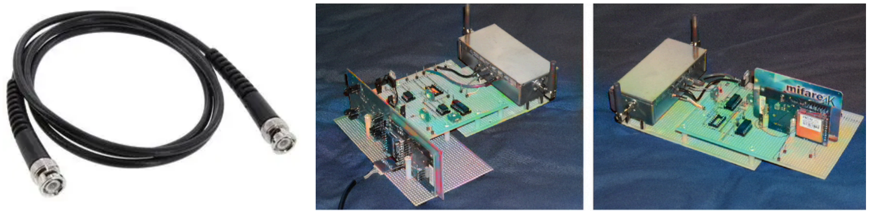


Fake terminal

~50 $ without PIN
Up to card limit with an unlocked phone

	Existing countermeasures
Logical layer relays	✓
Physical layer relays	✗ ~ km

 *

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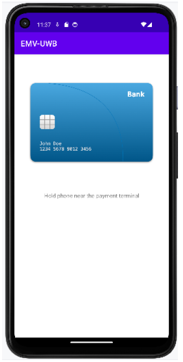
Relay Attacks on Contactless Payments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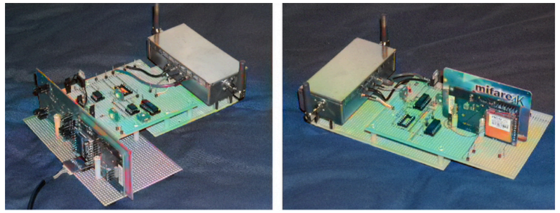

*

	Existing countermeasures	PURE
Logical layer relays	✓	✓
Physical layer relays	✗ ~ km	✓ ~ 50 cm

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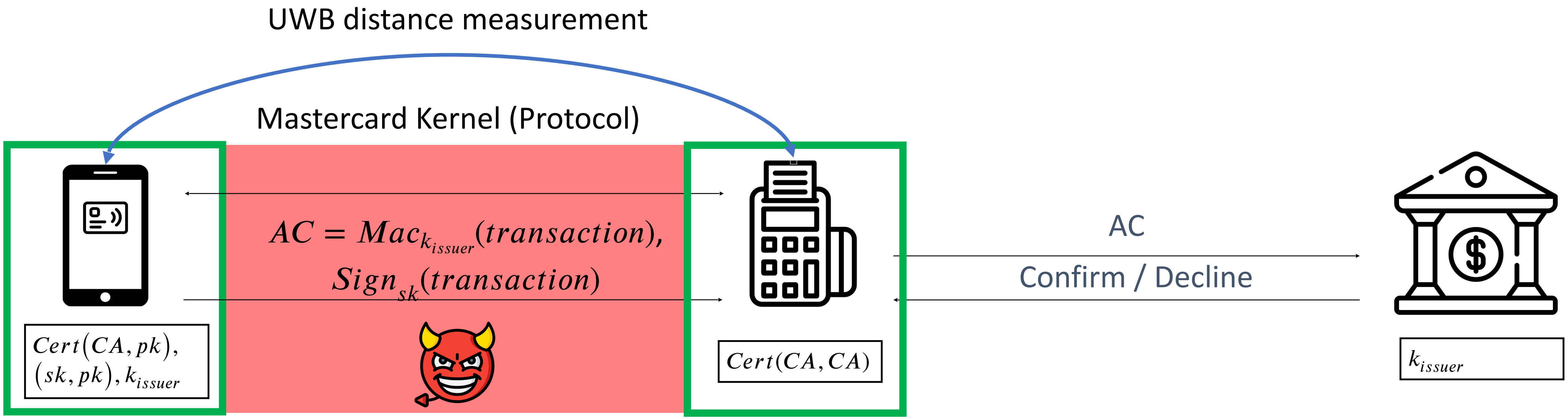
PURE in the Payment Ecosystem



UWB distance measurement

Mastercard Kernel (Protocol)

$AC = Mac_{k_{issuer}}(transaction),$

$Sign_{sk}(transaction)$

$Cert(CA, pk),$
$(sk, pk), k_{issuer}$

$Cert(CA, CA)$

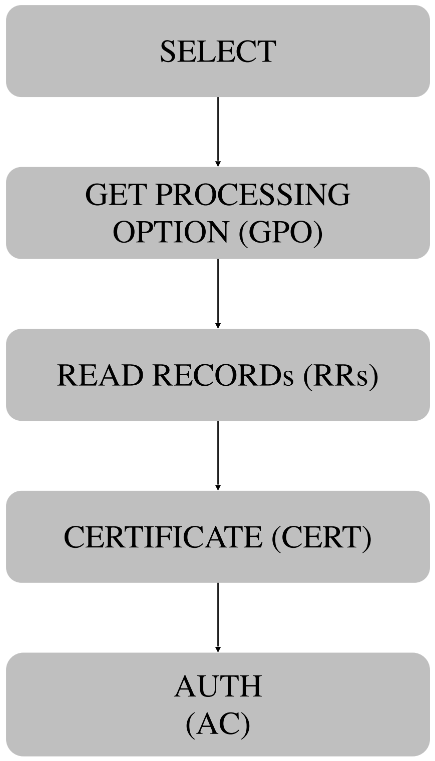
AC

Confirm / Decline

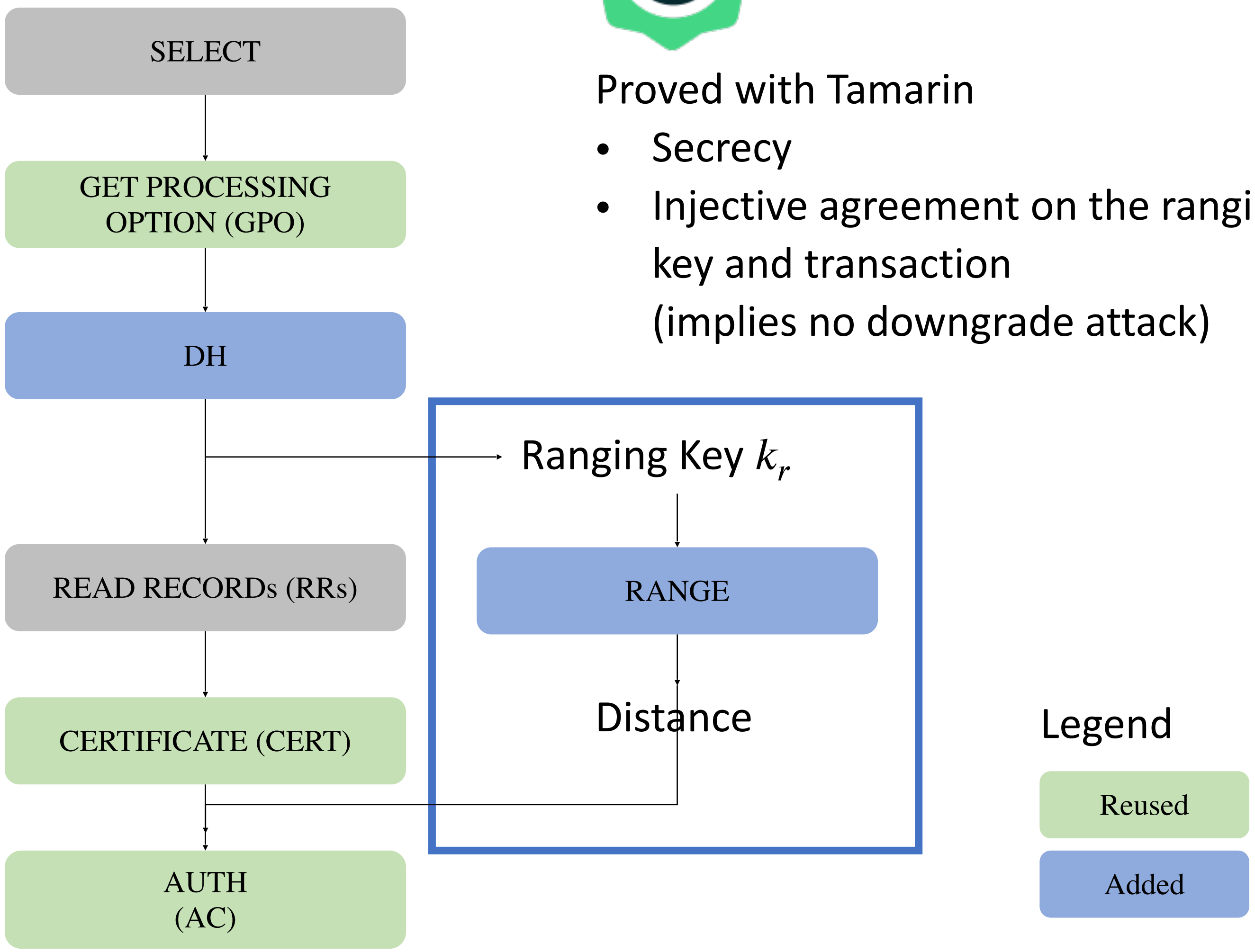
k_{issuer}

PURE specifically target
smartphone payments

PURE Protocol Extension



1. Mastercard Kernel

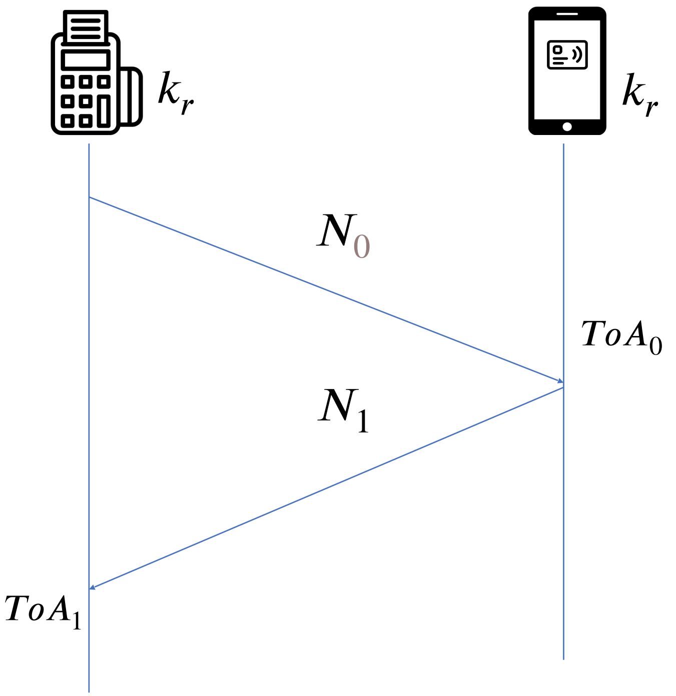


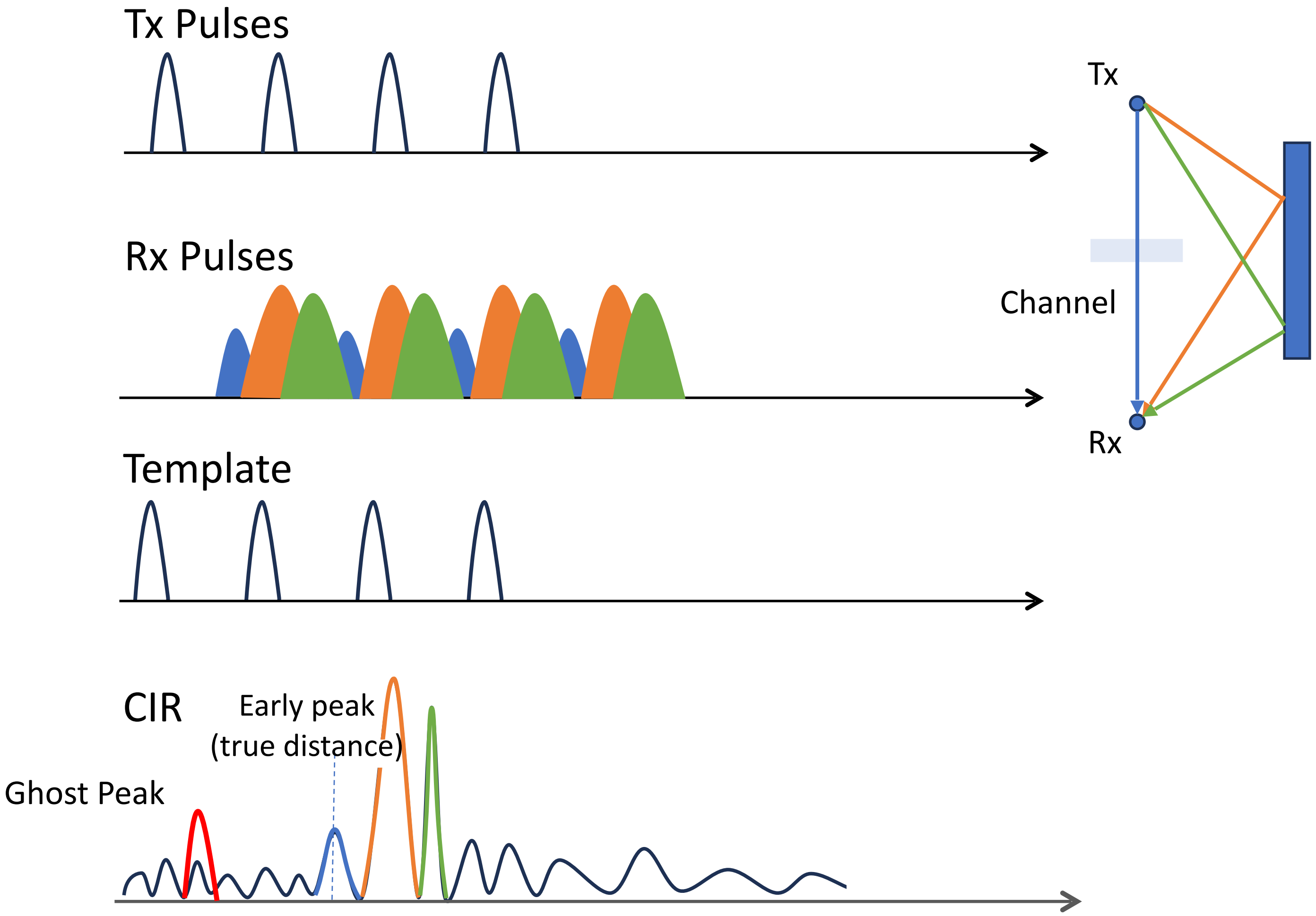
2. Mastercard Kernel + PURE

Proved with Tamarin

- Secrecy
- Injective agreement on the ranging key and transaction (implies no downgrade attack)

UWB Ranging



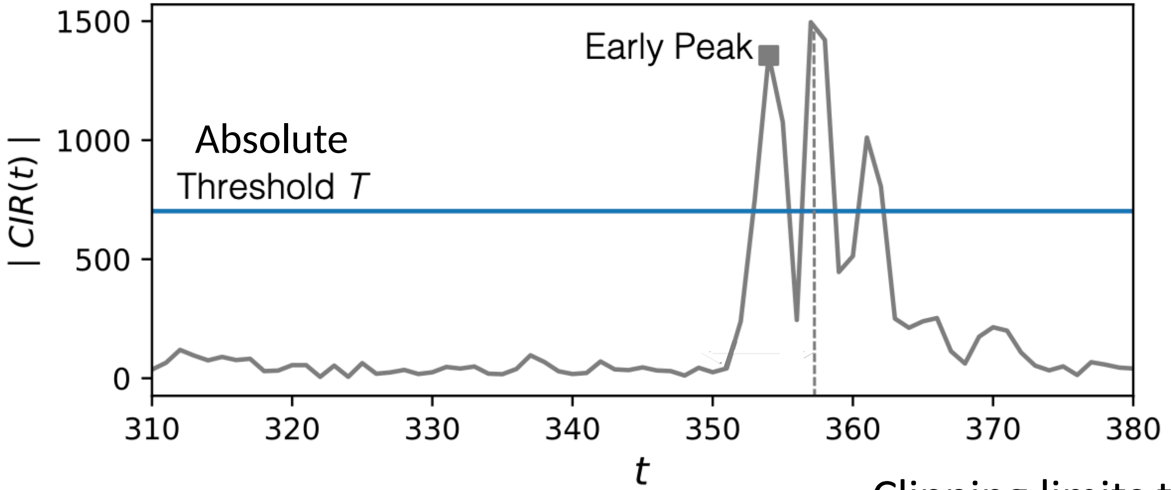


ToF = Time of Flight

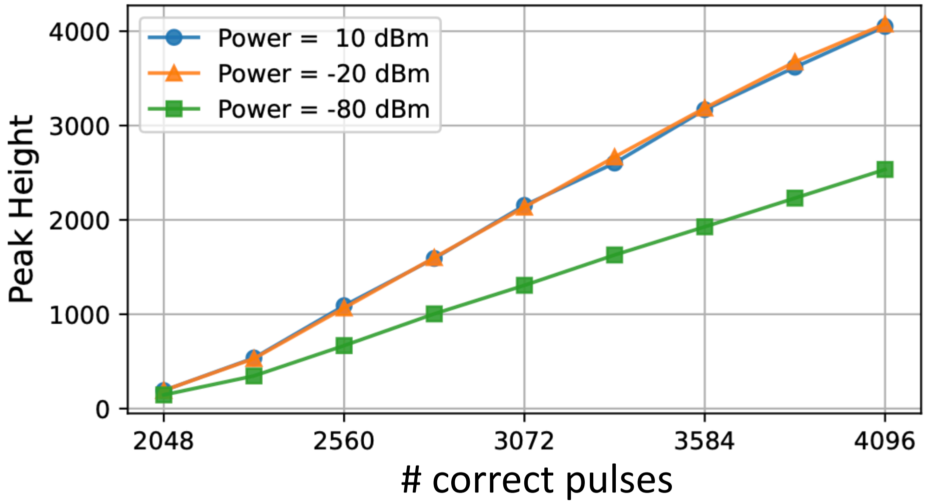
ToA = Time of Arrival

CIR = Channel Impulse Response

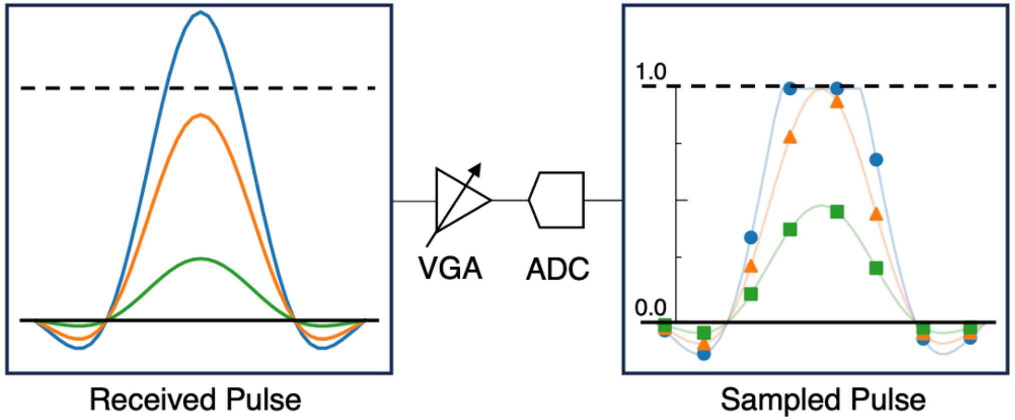
Security of the Time of Arrival Verification



More power⇏Higher peaks



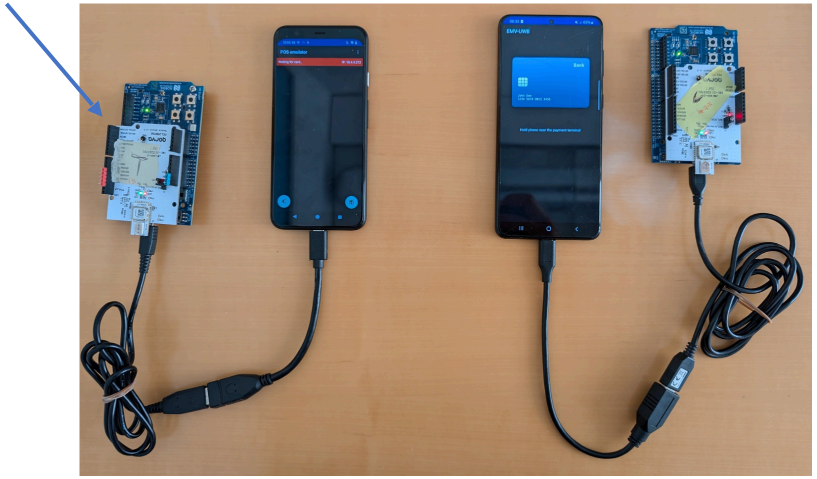
Clipping limits the contribution of each pulse



- A fixed threshold forces the adversary to correctly guess a certain amount of pulses
- We fix out threshold to limit the probability of a Ghost Peak attack to 2^{-48}

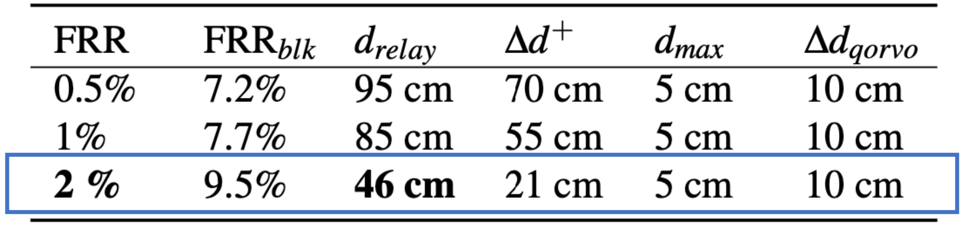
Putting it all together

External UWB chip for richer API

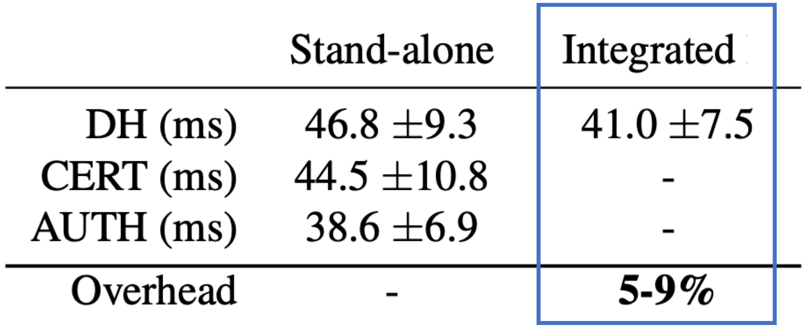


PURE terminal

PURE card



FRR	FRR$_{blk}$	d_{relay}	Δd^{+}	d_{max}	Δd_{qorvo}
0.5%	7.2%	95 cm	70 cm	5 cm	10 cm
1%	7.7%	85 cm	55 cm	5 cm	10 cm
2 %	9.5%	**46 cm**	21 cm	5 cm	10 cm



	Stand-alone	Integrated
DH (ms)	46.8 ±9.3	41.0 ±7.5
CERT (ms)	44.5 ±10.8	-
AUTH (ms)	38.6 ±6.9	-
Overhead	-	**5-9%**

Conclusion

Limitations

- PURE is not applicable to physical cards because not equipped with UWB chips
- PURE backward compatibility requires large deployments on terminals

Main contributions

- PURE protects mobile contactless transactions from relays greater than 50 cm
- The protocol extension was proven secure in Tamarin
- The ToA verification function protects against Ghost Peak attack
- The payment channels characterization shows PURE achieves high reliability (2% FRR)

Artifacts at
https://github.com/pure-uwb