ACACIA: A Practical, Privacy-Preserving Trigger-Action Platform using Multi-Party Computation

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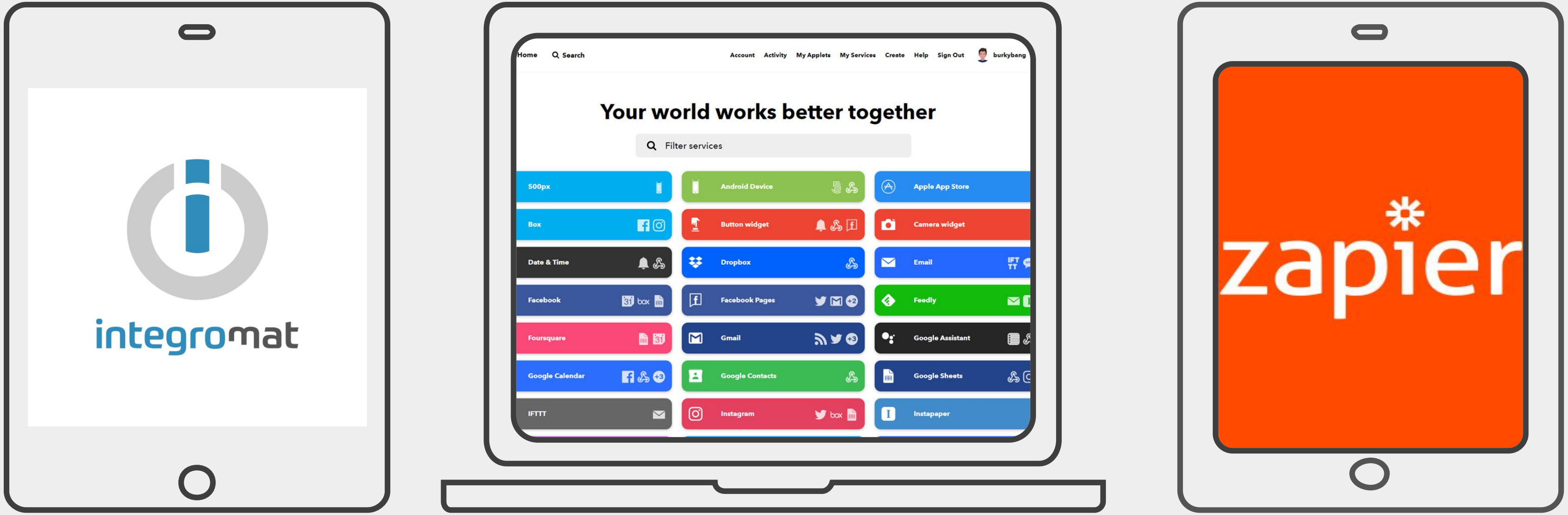
Trigger-Action Platforms (TAPs)

Market Analysis

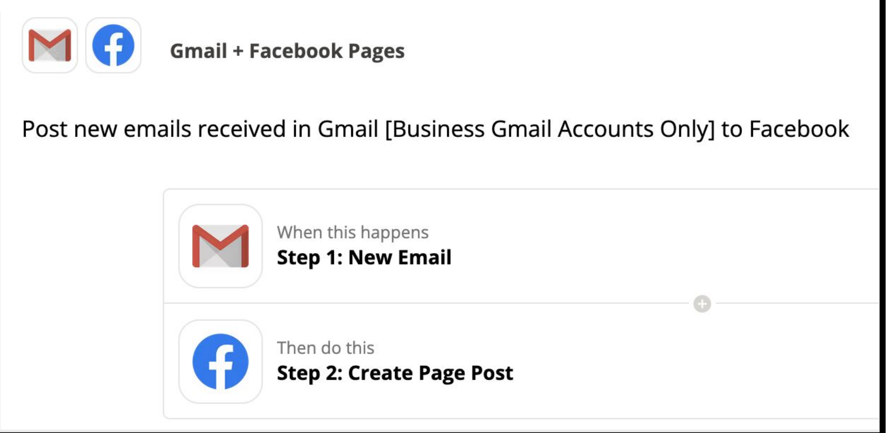


Today's TAPs

Plans	Charge	Zaps	Tasks / month	Update Time	Premium Applications
Free	0 \$ Free	5 Single-step	100	15 mins	-
Starter	19.99 \$ annual 24.99 \$ mon by mon	20 Multi-step	750	15 mins	3
Professional	49 \$ annual 61.25 \$ mon by mon	unlimited Multi-step	2000	2 mins	unlimited
Team	299 \$ annual 373.75 \$ mon by mon	unlimited Multi-step	50,000	1 min	unlimited
Company	599 \$ annual 784.75 \$ mon by mon	unlimited Multi-step	100,000	1 min	unlimited

Zapier pricing plans [1].

[Zapier templates]



- the services (both trigger and action, for example Gmail and Facebook),
- the recipe semantics ("If new email – post it to a Facebook page."),
- inputs to the applet (email,), and
- outputs to the action service (the Facebook post),
- improve performance.

Multi-Party Computation

Assumes direct secure channels between each pair and denotes encryption and decryption of a message m under key κ as Encκ (m) and Decκ (m) with the goal to learn the correct output of a mutual function without revealing private inputs.

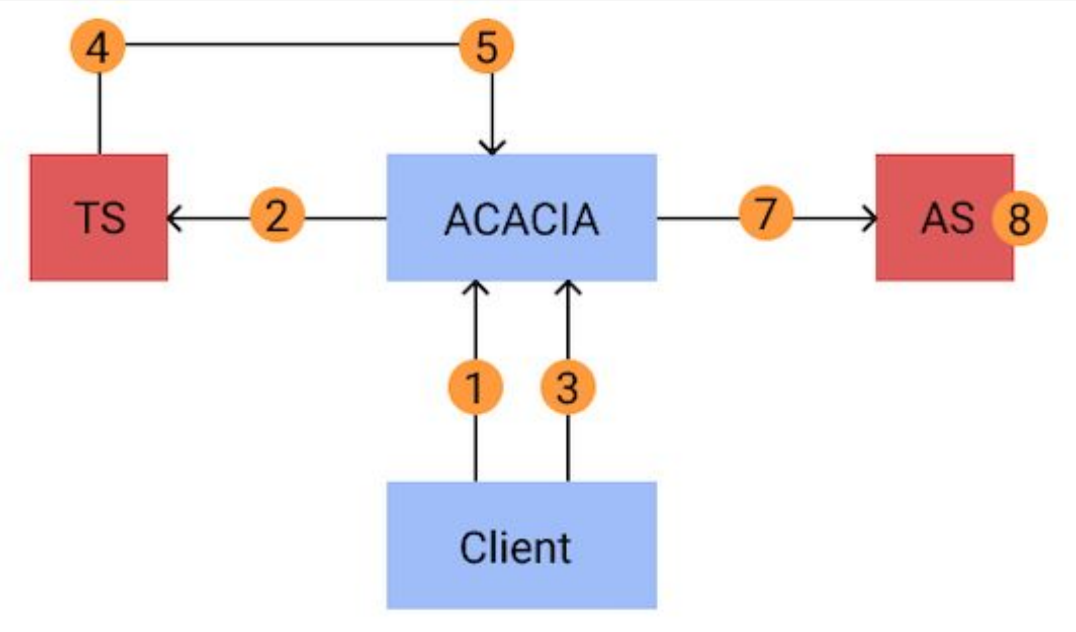
Garbled Circuits

Yao's Garbled Circuits operate on the idea that there is a function $F(x,y)$, party $P1$ holds $x \in X$, and party $P2$ holds $y \in Y$.

Real-ideal Paradigm

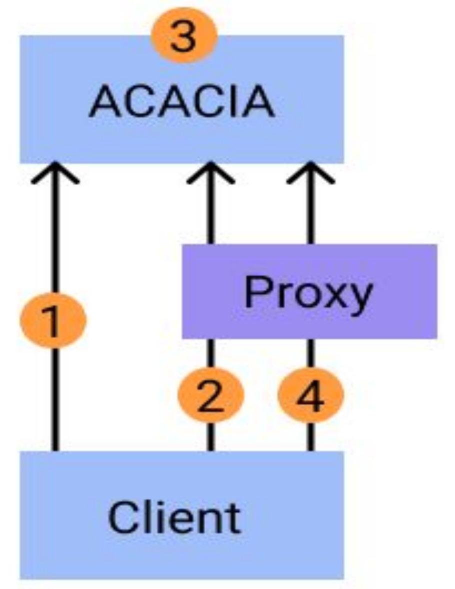
Realπ $(\kappa, C, x1, ..., xn)$ Idealϕ,Sim$(\kappa,C,x1,...,xn)$ are indistinguishable in κ.

Basic Protocol



Basic protocol recipe installation scheme. (1) - recipe installation; (2) - send encrypted recipe information; (3) - generate and send garbled circuits; (4) - get trigger data xt and execute $P(xt,ct)$; (5) - garbled inputs for $f\,(xt,ct)$; (6) - execute $f\,(xt,ca)$; (7) - send y; (8) - decrypt y to get action data.

Anonymity Extension



Anonymous recipe instalation protocol scheme. (1) - Get anonymous tokens; (2) - send recipe installation data with anonymous token; (3) - check token validity, install the recipe if valid; (4) - upload garbled circuits with authorization token. The rest of the steps follow the scheme in Figure 1.

Implementation

Rust:

- Fast
- Extensive support
- Efficient
- High safety

C++ MPC library:
https://github.com/emp-toolkit/emp-sh2pc

Java mobile client.

```
fn encrypt_msg(
    msg: &[u8],
    aad: &[u8],
    server_pk: &<Kem as KemTrait>::PublicKey,) -> (<Kem as KemTrait>::E
        let mut csprng = StdRng::from_entropy();

        // encapsulate a key and use the resulting shared secret to enc
        // encrypt with AEAD context
        let (encapsulated_key, mut sender_ctx) = hpke::setup_sender::<A
                                                  (&OpModeS::Base, &s
                                                  &mut csprng).expect
        // seal in place will encrypt the plaintext in place if success
        let mut msg_copy = msg.to_vec();
        let tag = sender_ctx.seal_in_place_detached(&mut msg_copy, aad)

        let ciphertext = msg_copy;
        println!("ciphertext: {:?}", ciphertext);
        // return
        (encapsulated_key, ciphertext, tag)
    }
```

Evaluation Metrics

What are the computation and communication costs for each of the parties in our system?

How do the added privacy and anonymity guarantees affect the latency and throughput of our system?

Throughput

Latency

Future Work Directions

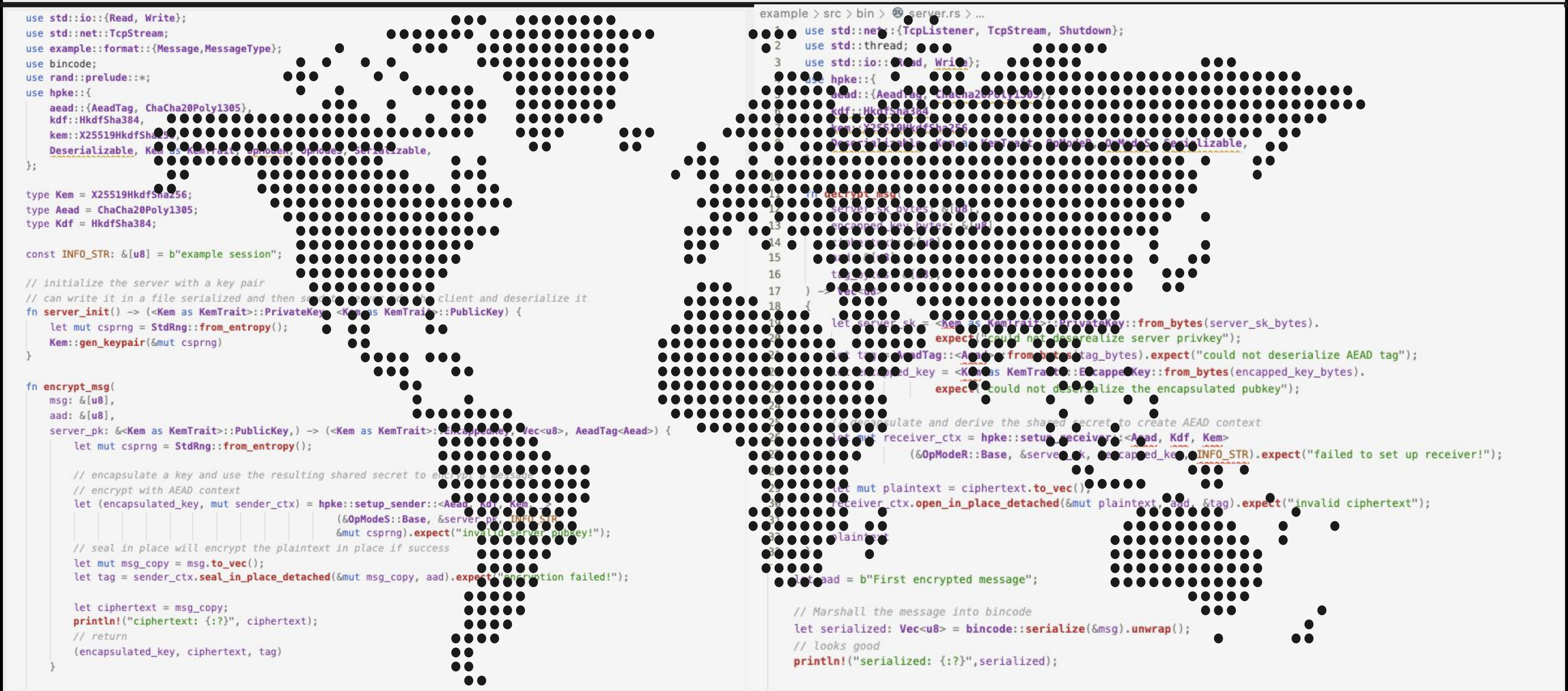
Running the system on real-world workloads and comparing with current TAPs

Tokens and proxy improvement

Anonymity without a proxy

Better performance, general mpc betterment

Conclusion


use std::io::{Read, Write};
use std::net::TcpStream;
use example::format::{Message,MessageType};
use bincode;
use rand::prelude::*;
use hpke::{
aead::{AeadTag, ChaCha20Poly1305},
kdf::HkdfSha384,
};
type Aead = ChaCha20Poly1305;
type Kdf = HkdfSha384;
const INFO_STR: &[u8] = b"example session";
// initialize the server with a key pair
fn server_init() -> (<Kem as KemTrait>::PrivateKey,
let mut csprng = StdRng::from_entropy();
Kem::gen_keypair(&mut csprng)
fn encrypt_msg(
msg: &[u8],
aad: &[u8],
let mut csprng = StdRng::from_entropy();
// encrypt with AEAD context
let (encapsulated_key, mut sender_ctx) = hpke::setup_sender::<Aead
// seal in place will encrypt the plaintext in place if success
let mut msg_copy = msg.to_vec();
let tag = sender_ctx.seal_in_place_detached(&mut msg_copy, aad).expect
let ciphertext = msg_copy;
println!("ciphertext: {:?}", ciphertext);
// return
(encapsulated_key, ciphertext, tag)
example › src › bin › server.rs › ...
use std::net::{TcpListener, TcpStream, Shutdown};
use std::thread;
let mut plaintext = ciphertext.to_vec();
let aad = b"First encrypted message";
// Marshall the message into bincode
let serialized: Vec<u8> = bincode::serialize(&msg).unwrap();
// looks good
println!("serialized: {:?}",serialized);

References

[1] Mohammed Abdou, Abdelrahman M.Ezz, and Ibrahim Farag. 2021. Digital Automation Platforms Comparative Study. In 4th International Conference on Information and Computer Technologies, ICICT 2021, Kahului, HI, USA, March 11-14, 2021. IEEE, 279–286. https://doi.org/ 10.1109/ICICT52872.2021.00052

[2] Yunang Chen, Amrita Roy Chowdhury, Ruizhe Wang, Andrei Sabelfeld, Rahul Chatterjee, and Earlence Fernandes. 2021. Data Privacy in Trigger-Action Systems. In 42nd IEEE Symposium on Security and Privacy, SP 2021, San Francisco, CA, USA, 24-27 May 2021. IEEE, 501–518. https://doi.org/10.1109/SP40001.2021.00108

[3] SandySchoettler,AndrewThompson,RakshithGopalakrishna,and Trinabh Gupta. 2020. Walnut: A low-trust trigger-action platform. CoRR abs/2009.12447 (2020). arXiv:2009.12447 https://arxiv.org/abs/ 2009.12447

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[5] David Evans, Vladimir Kolesnikov, and Mike Rosulek. 2018. A Pragmatic Introduction to Secure Multi-Party Computation. Found. Trends Priv. Secur. 2, 2-3 (2018), 70–246. https://doi.org/10.1561/3300000019

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Find more information in the report paper.