# An enhanced socket API for Multipath TCP


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# Outline

- **Multipath TCP**
- The proposed socket API

# What is Multipath TCP ?

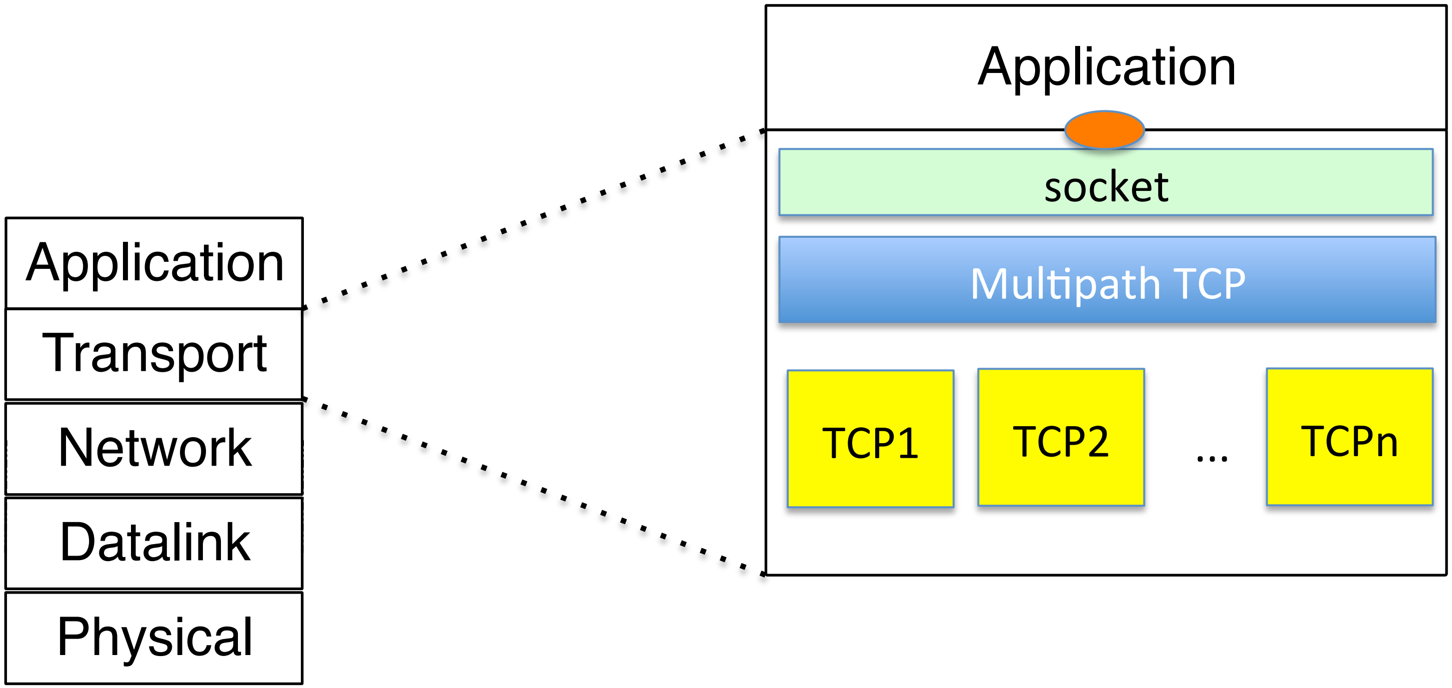
- A recently standardised TCP extension that allows packets belonging to one connection to be sent over different paths

  – Both WiFi and LTE on smartphones
  – Both IPv6 and IPv4 on dual-stack but single-homed hosts
  – Leveraging Equal Cost Multipath in datacenters

# Multipath TCP

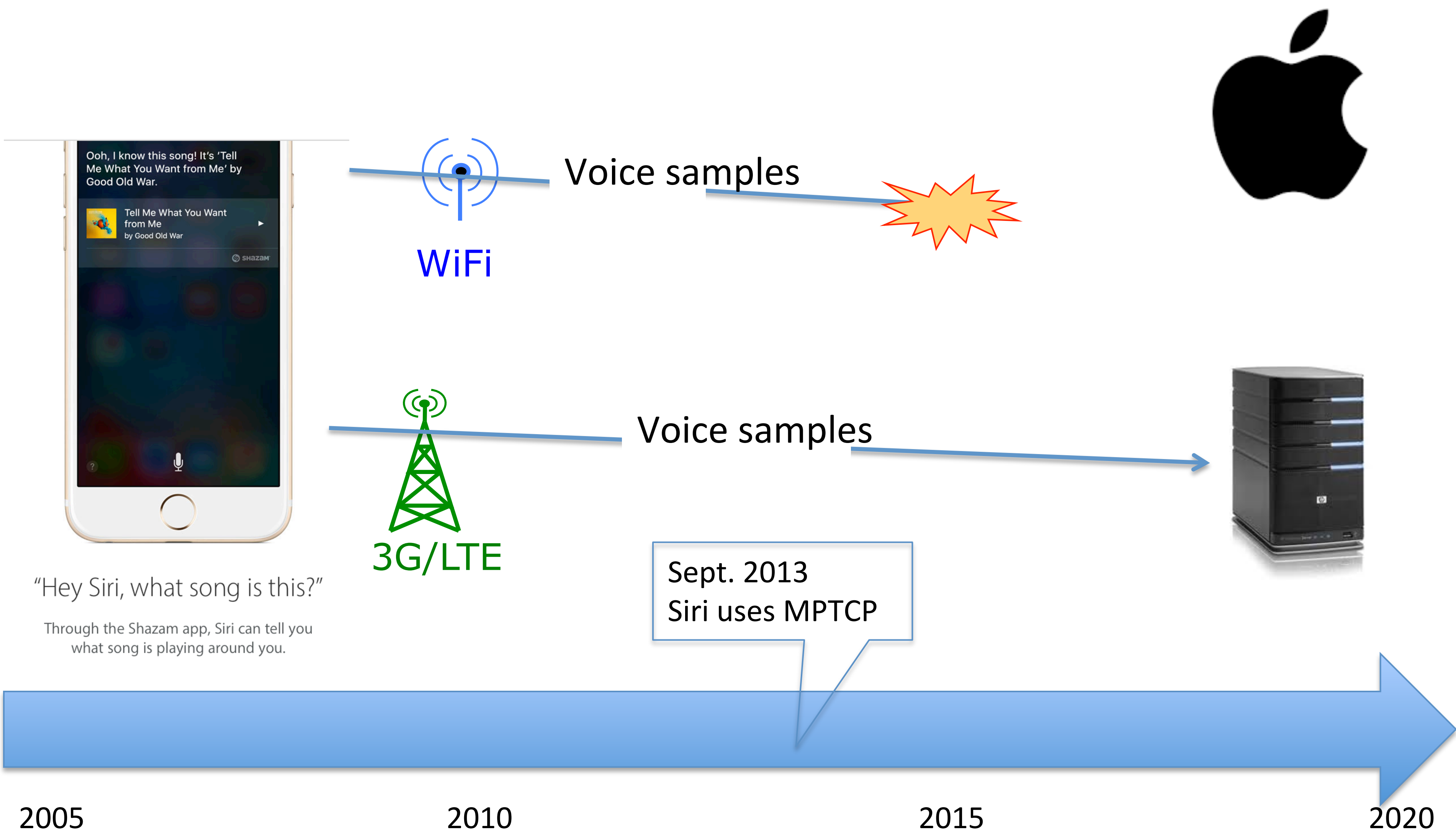
- Multipath TCP is an *evolution* of TCP
- Design objectives
  - Support unmodified applications
  - Work over today's networks (IPv4 and IPv6)
  - Work in all networks where regular TCP works

# Multipath TCP and the architecture

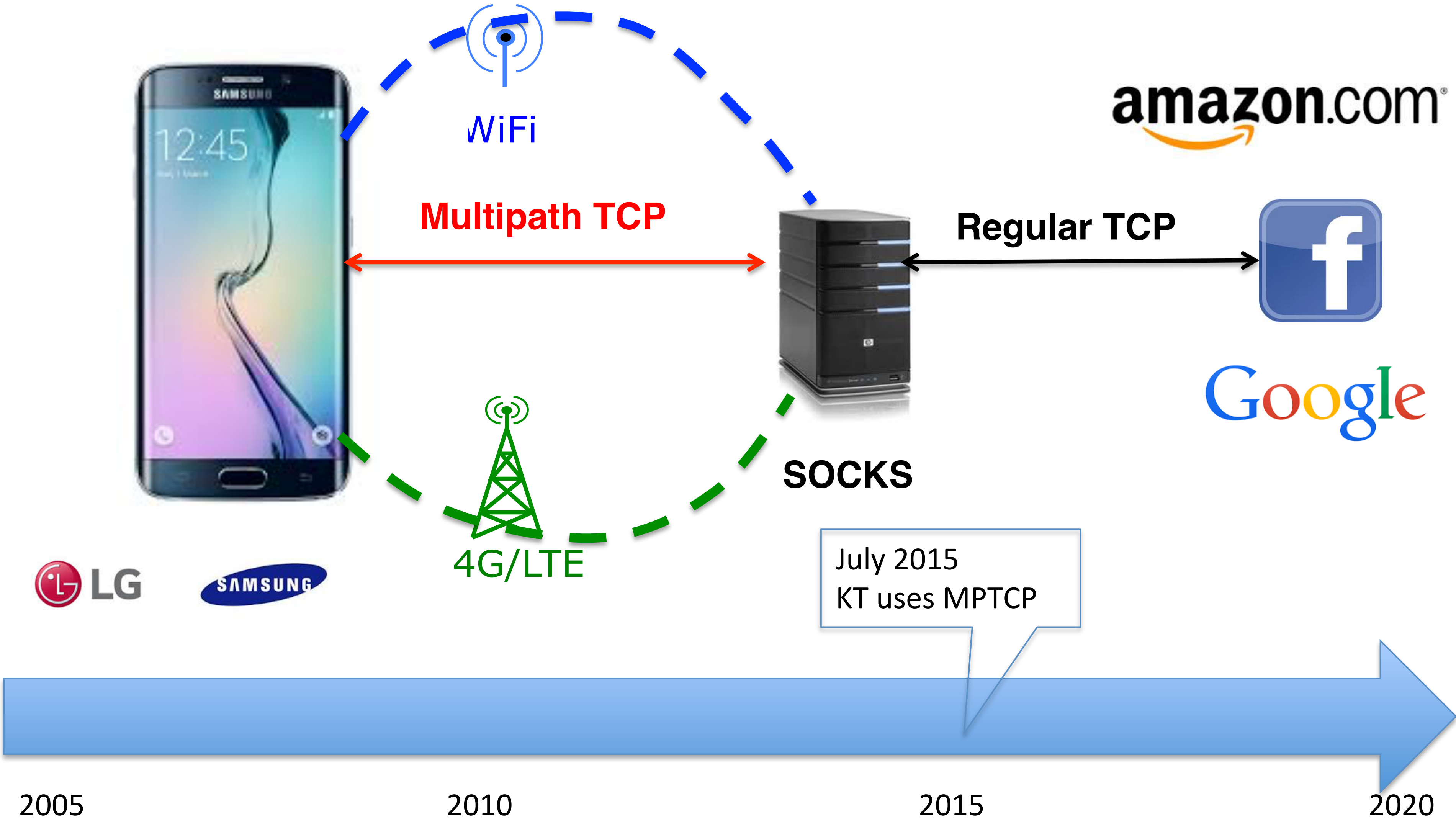



A. Ford, C. Raiciu, M. Handley, S. Barre, and J. Iyengar, "Architectural guidelines for multipath TCP development", RFC6182 2011.

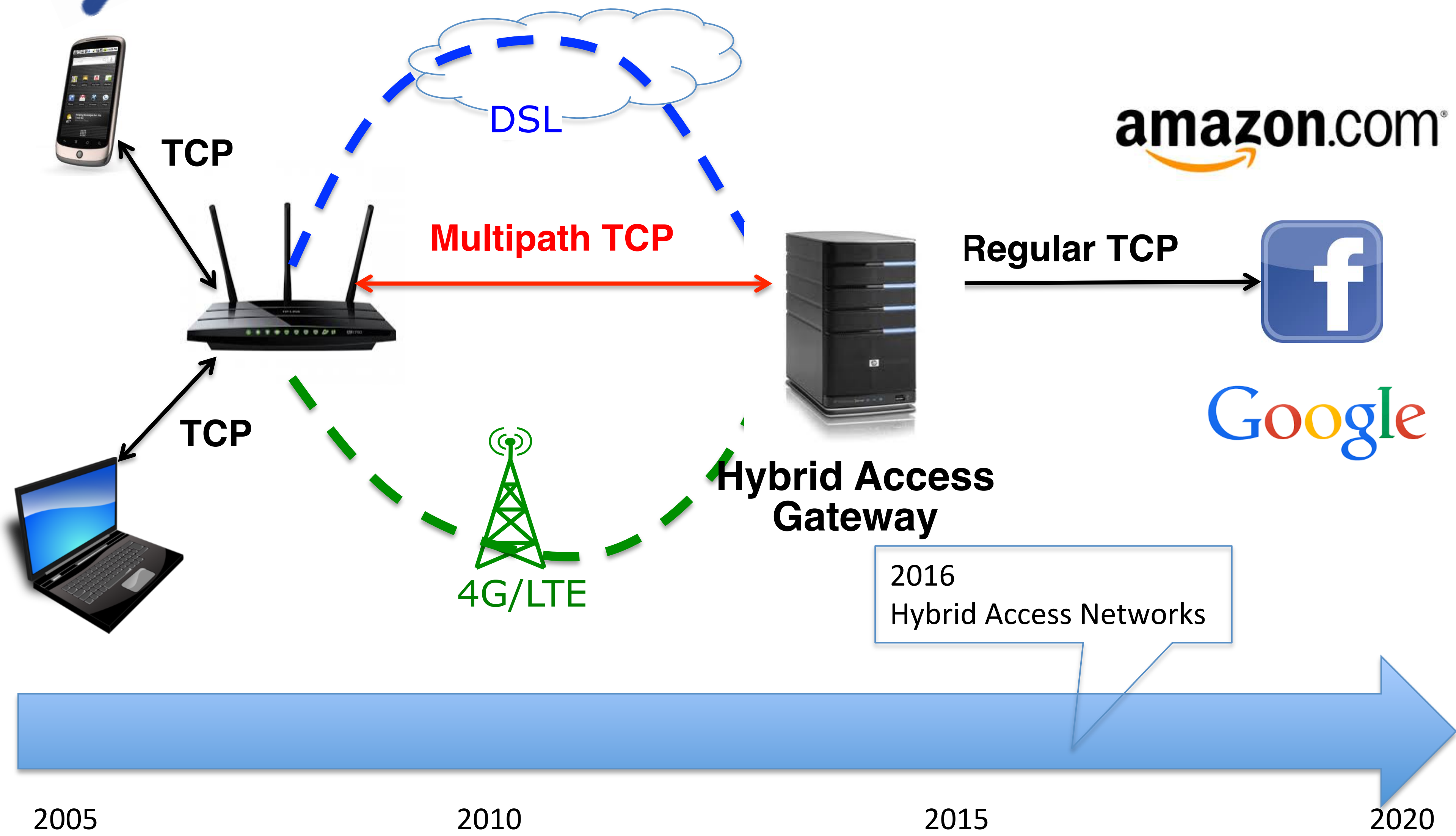
# Low-latency for Siri



# WiFi/LTE Bonding



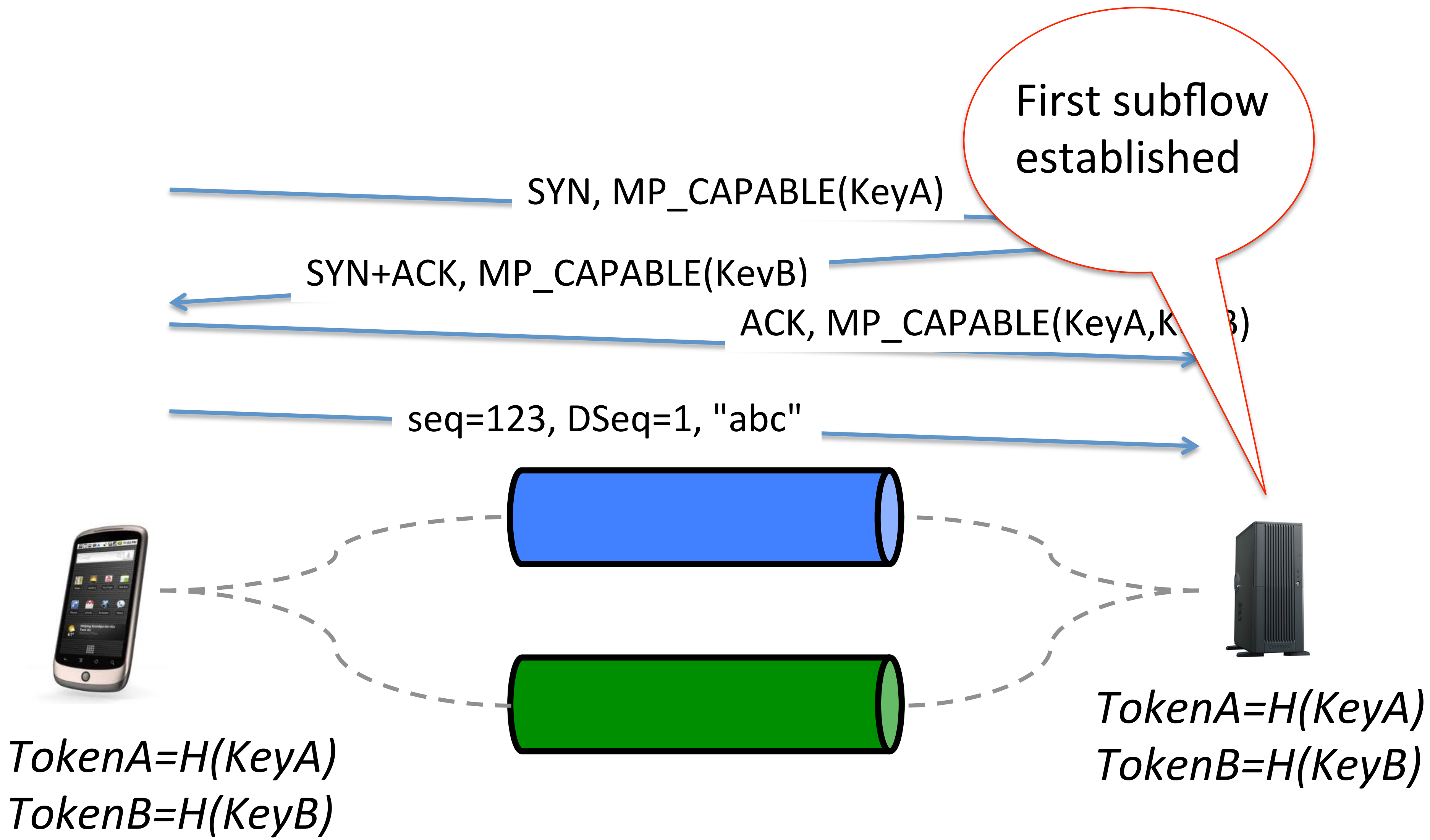
# Hybrid Access Networks



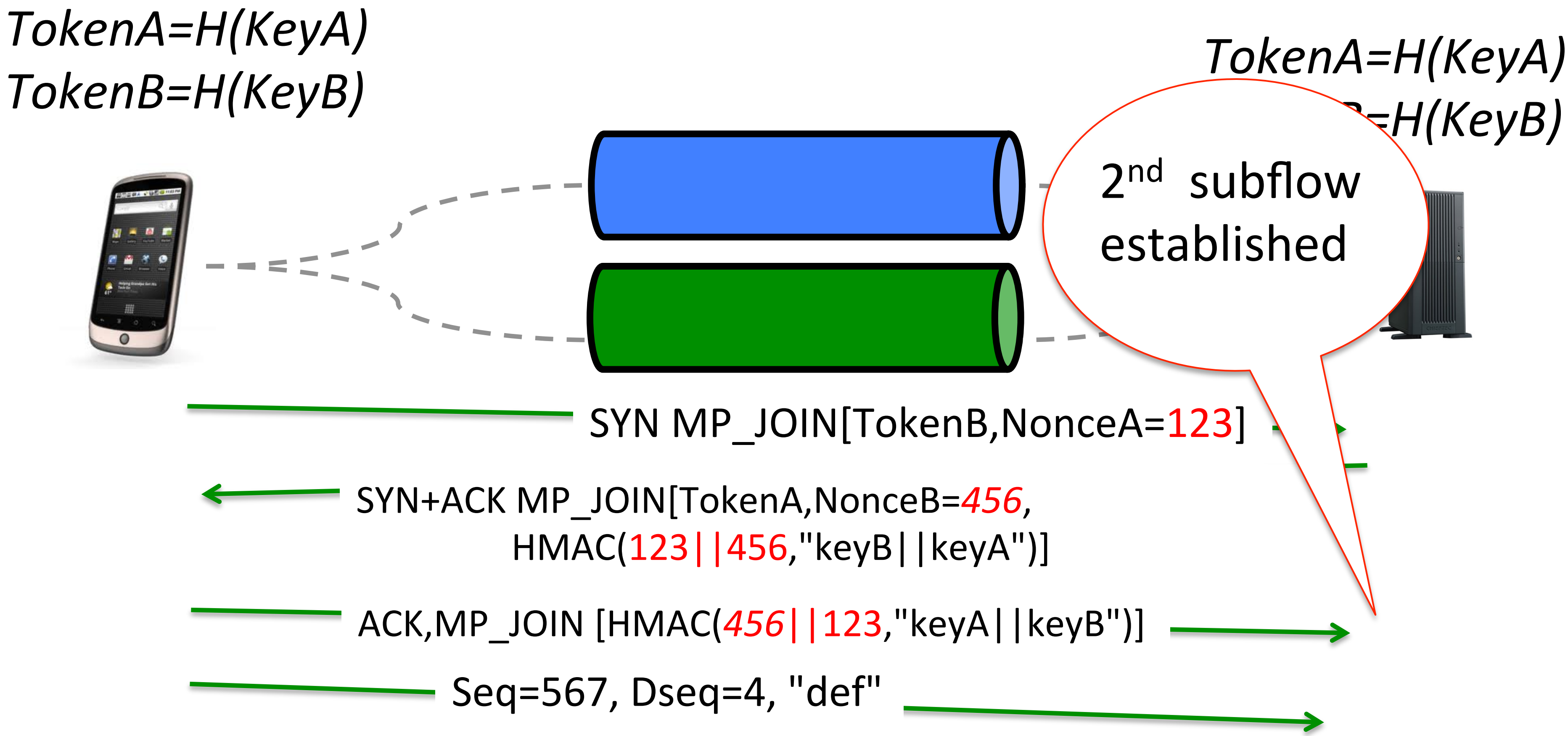
# Sending data over different paths ?

- *A Multipath TCP connection is composed of one or more regular TCP subflows that are combined*
  - Each host maintains state that glues the TCP subflows that compose a Multipath TCP connection together
  - Each TCP subflow is sent over a single path and appears like a **regular TCP** connection along this path

# Multipath TCP
# Connection establishment



# Establishment of the second subflow



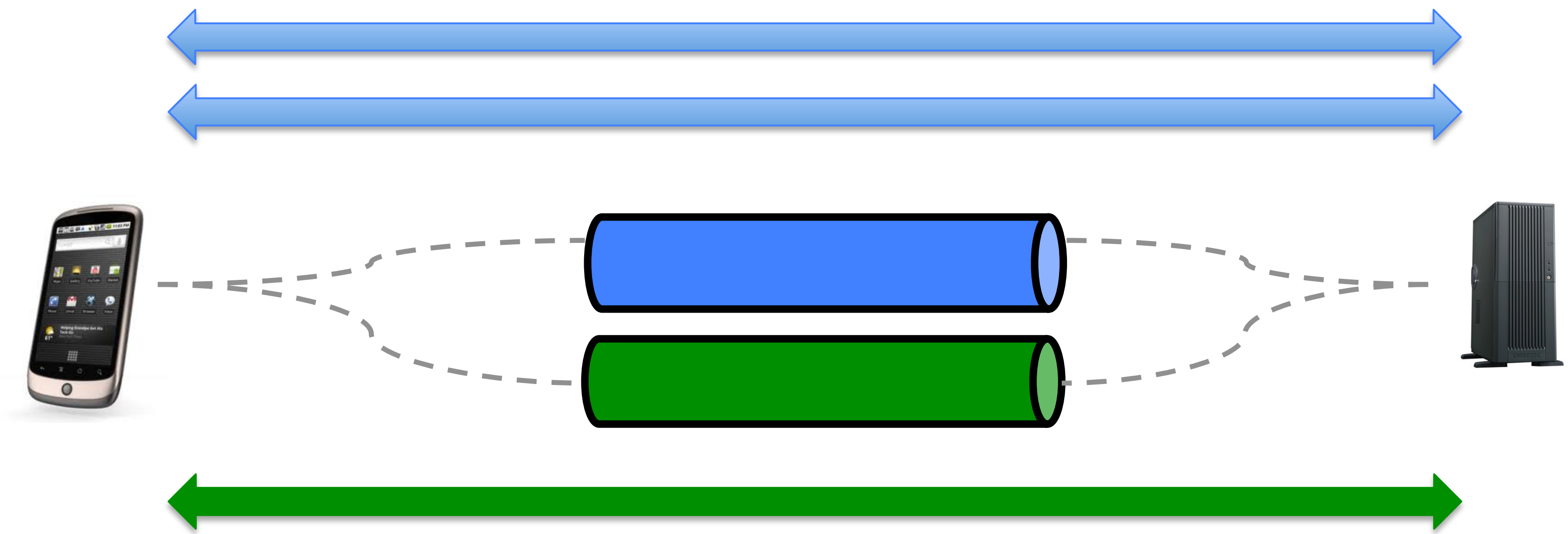
# TCP subflows

- Which subflows can be associated to a Multipath TCP connection ?

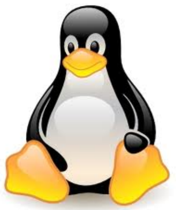
  – At least one of the elements of the four-tuple needs to differ between two subflows
    - Local IP address
    - Remote IP address
    - Local port
    - Remote port

# Subflow agility

- Multipath TCP supports
  - addition of subflows
  - removal of subflows



# How to control these subflows ?



- Current reference implementation on Linux
  - Standard socket API to support existing applications

- Subflows are managed by the path manager kernel module
  - Full-mesh
  - NDiffports

# How to control these subflows ?

iOS

```
/* socket creation */
s = socket(AF_MULTIPATH, SOCK_STREAM, IPPROTO_TCP);

/* creation of first subflow */
sa_endpoints_t endpoints;
/* any source interface */
endpoints.sae_srcif = 0;
/* any address of the client */
endpoints.sae_srcaddr = NULL;
endpoints.sae_srcaddrlen = 0;
/* server address */
endpoints.sae_dstaddr = (struct sockaddr *)
                             daddr->ai_addr;
endpoints.sae_dstaddrlen = daddr->ai_addrlen;

int rc = connectx(s, &endpoints, SAE_ASSOCID_ANY,
                  0, NULL, 0, NULL, NULL);
```

Special AF

Other system calls

# Outline

- Multipath TCP
- **The proposed socket API**

# Why using socket options ?

- `getsockopt` and `setsockopt` are well-known and extensible
- Relatively easy to implement a new socket option
- Can pass information from app to stack as memory buffer
- Can retrieve information from stack to app as memory buffer

# The MPTCP socket options

- **MPTCP_GET_SUB_IDS**
  - Retrieve the ids of the different subflows
- **MPTCP_GET_SUB_TUPLE**
  - Retrieve the endpoints of a specific subflow
- **MPTCP_OPEN_SUB_TUPLE**
  - Create a new subflow with specific endpoints
- **MPTCP_CLOSE_SUB_ID**
  - Closes one of the established subflows
- **MPTCP_SUB_GETSOCKOPT** and **MPTCP_SUB_SETSOCKOPT**
  - Apply a TCP socket option on a specific subflow

# Currently established subflows

```
int i;
unsigned int optlen;
struct mptcp_sub_ids *ids;

optlen = 42; // must be large enough

ids = (struct mptcp_sub_ids *) malloc(optlen);

err=getsockopt(sockfd, IPPROTO_TCP,
                    MPTCP_GET_SUB_IDS, ids, &optlen);

for(i = 0; i < ids->sub_count; i++){
      printf("Subflow id : %i\n",
                ids->sub_status[i].id);
  }
```

Subflow id

# What are the endpoints of a subflow ?

```
unsigned int optlen;
struct mptcp_sub_tuple *sub_tuple;

optlen = 100; // must be large enough
sub_tuple = (struct mptcp_sub_tuple *)malloc(op

sub_tuple->id = sub_id;
getsockopt(sockfd, IPPROTO_TCP, MPTCP_GET_SUB_TUPLE,
               sub_tuple,&optlen);
sin = (struct sockaddr_in*) &sub_tuple->addrs[0];

printf("\tip src : %s src port : %hu\n", inet_ntoa(sin->sin_addr),
                                             ntohs(sin->sin_port));
sin = (struct sockaddr_in*) &sub_tuple->addrs[1];

printf("\tip dst : %s dst port : %hu\n", inet_ntoa(sin->sin_addr),
                                             ntohs(sin->sin_port));
```

Local endpoint

Remote endpoint

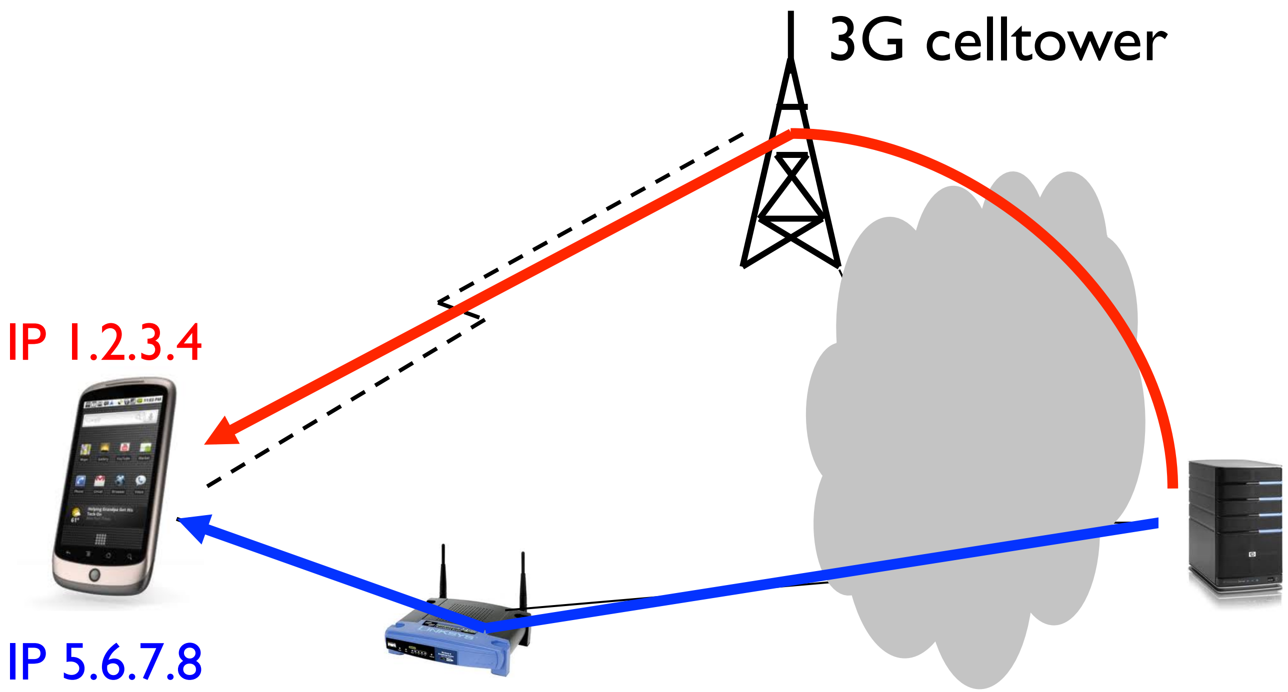
# Creating a subflow

```
unsigned int optlen;
struct mptcp_sub_tuple *sub_tuple;
struct sockaddr_in *addr;

optlen = sizeof(struct mptcp_sub_tuple) +
               2 * sizeof(struct sockaddr_in));
sub_tuple = malloc(optlen);
sub_tuple->id = 0; sub_tuple->prio = 0;

addr = (struct sockaddr_in*) &sub_tuple->addrs[0];
addr->sin_family = AF_INET;
addr->sin_port = htons(12345);
inet_pton(AF_INET, "10.0.0.1", &addr->sin_addr);
addr = (struct sockaddr_in*) &sub_tuple->addrs[1];
addr->sin_family = AF_INET;
addr->sin_port = htons(1234);
inet_pton(AF_INET, "10.1.0.1", &addr->sin_addr);
error =  getsockopt(sockfd, IPPROTO_TCP,
            MPTCP_OPEN_SUB_TUPLE, sub_tuple, &optlen);
```

Local endpoint

Remote endpoint

# Utilization of the socket API




**MPTCP enabled applications will be able to accurately control their usage of the cellular and WiFi interfaces**

# Conclusion and next steps

- Multipath TCP is getting deployed
  - Special applications (Siri) and on middleboxes
- Socket API will enable application developers to take full control of the underlying MPTCP
  - Create/delete/query subflows, apply options
  - Next steps
    - non-blocking I/O and events with `select`, `recvmsg` and `sendmsg`
    - Address management and advertisement
    - More options to control stack (e.g. scheduler)
- Cooperation with application developers