XDP offload using Nanotube

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XDP offload benefits

Give performance back to the application

- Reduce CPU usage
- Reduce memory/cache bandwidth usage

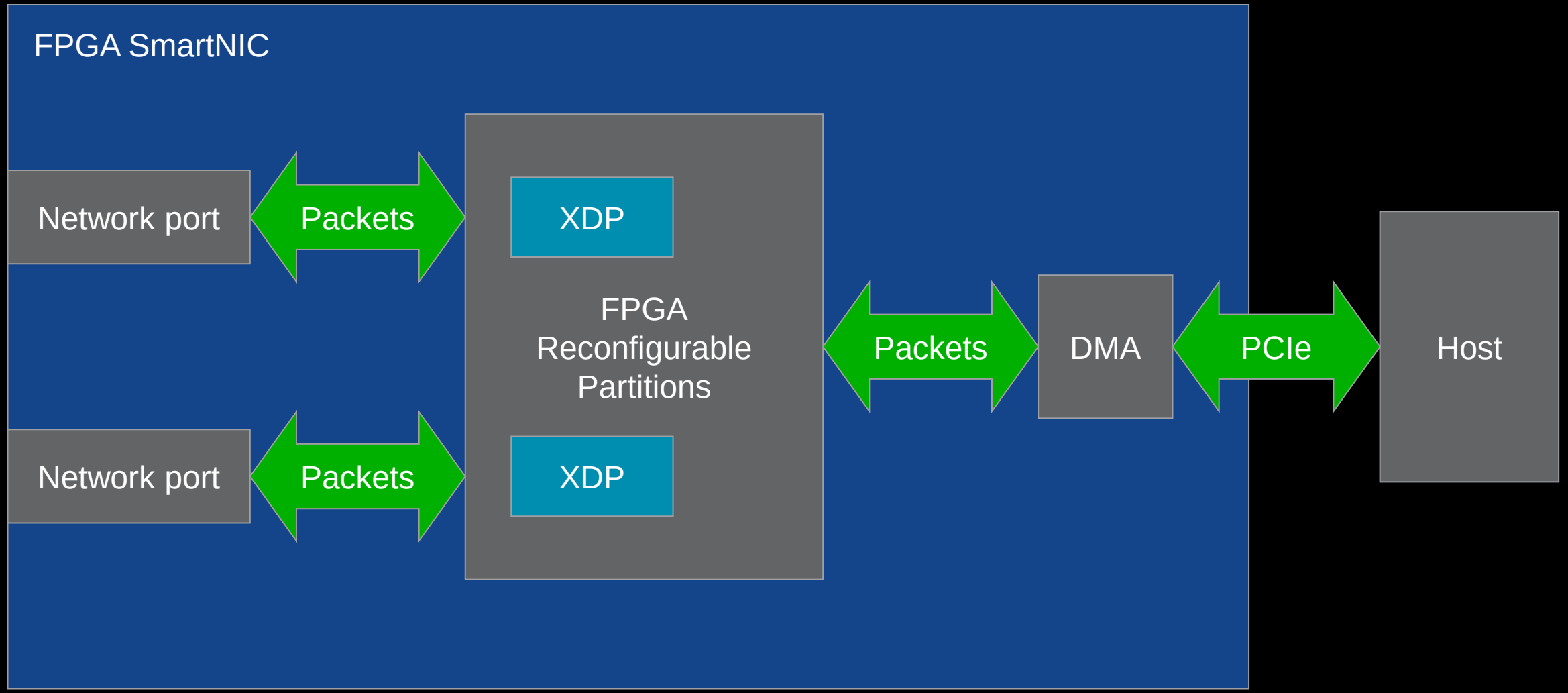
Target use cases

- Packet filtering (e.g., Firewall/DOS filter)
- Port redirection (e.g., Cluster load balancer)
- RX queue redirection (e.g., Host load balancer)

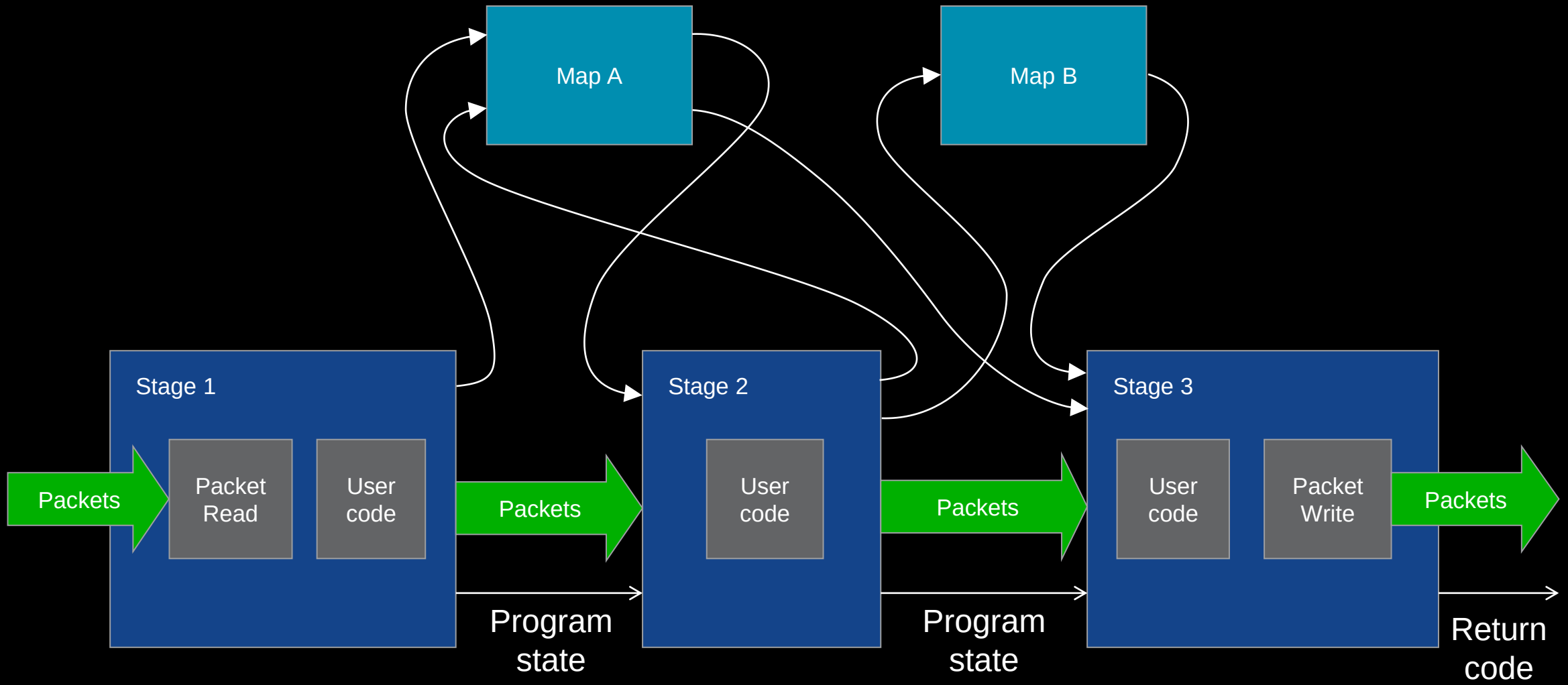
Use eBPF for compatibility

- Easy to program
- Existing programs

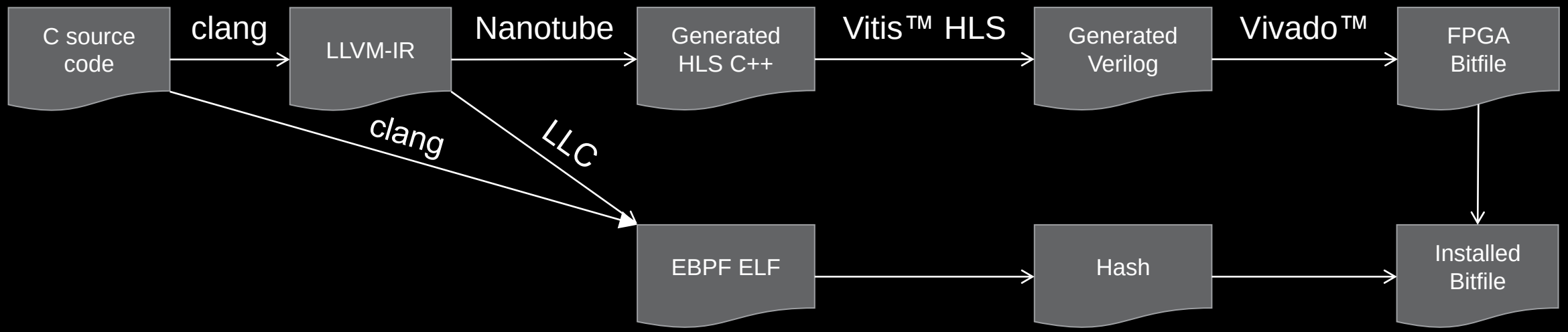
What is an FPGA SmartNIC?



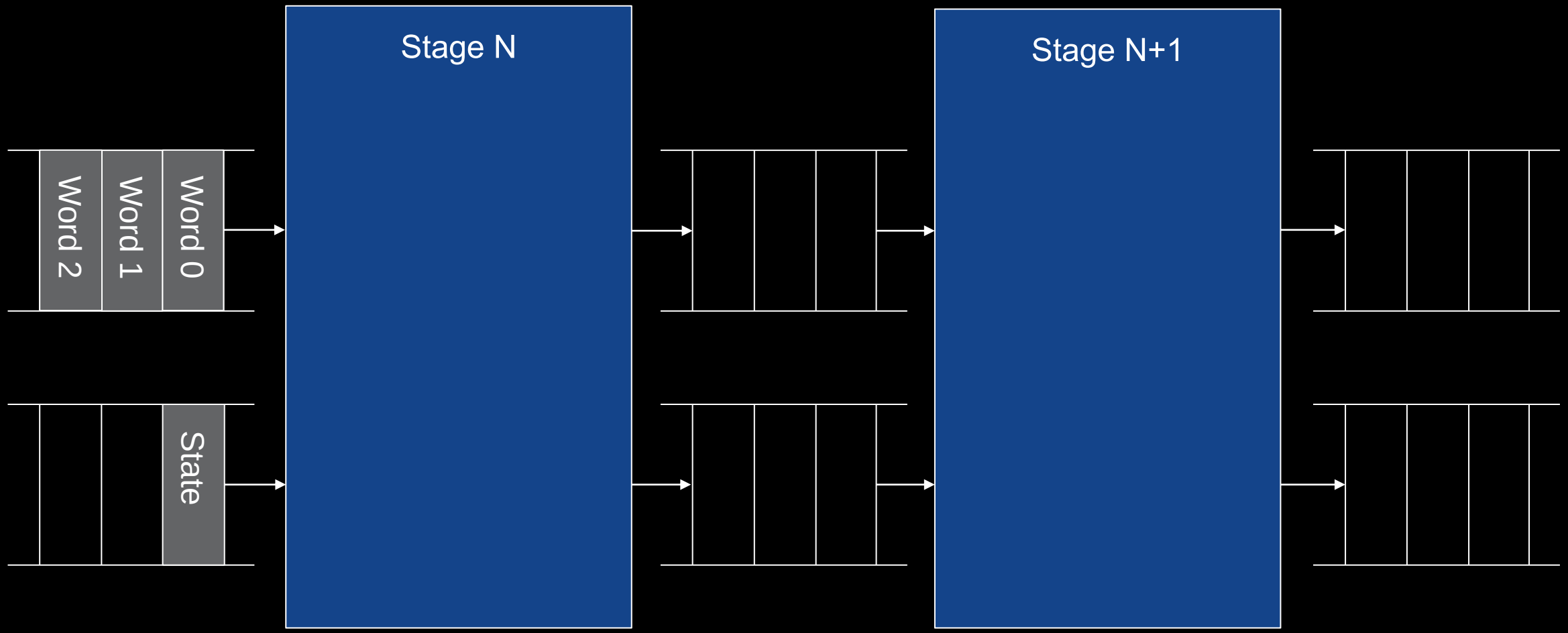
Compiling the program to FPGA logic



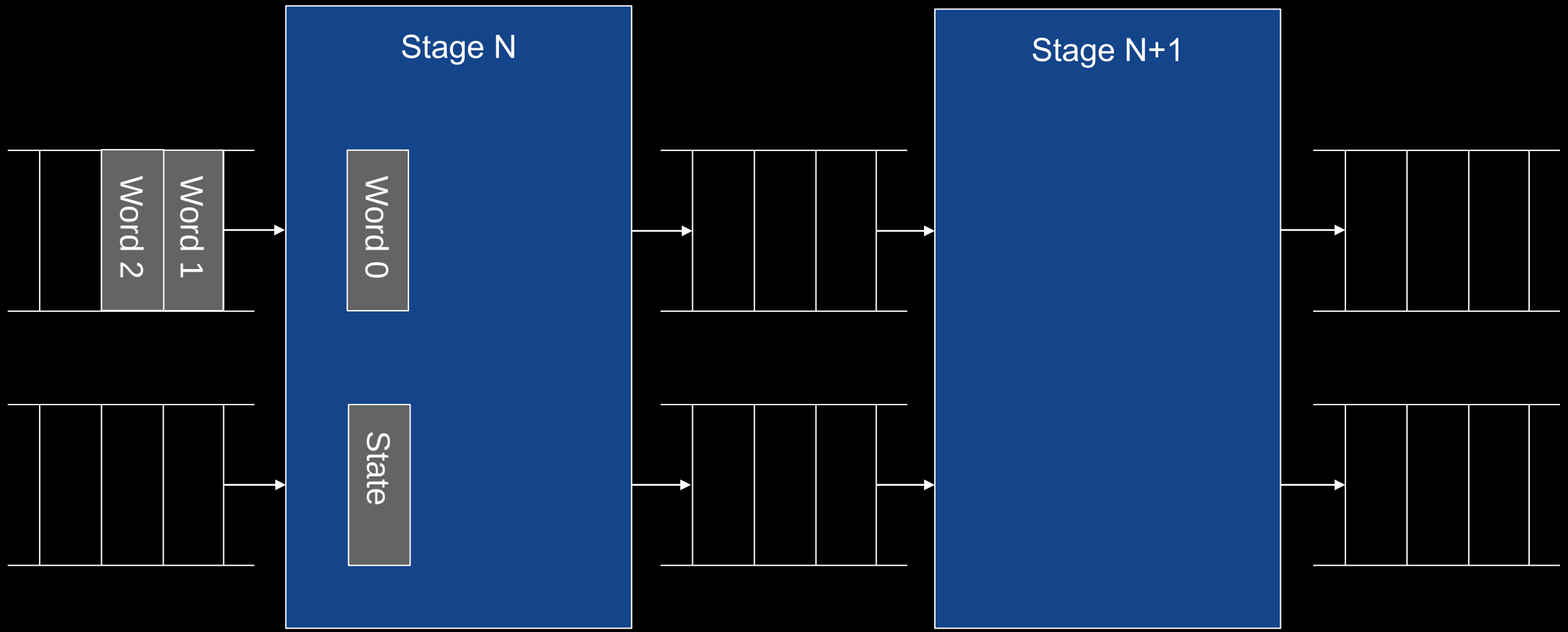
Nanotube compilation flow



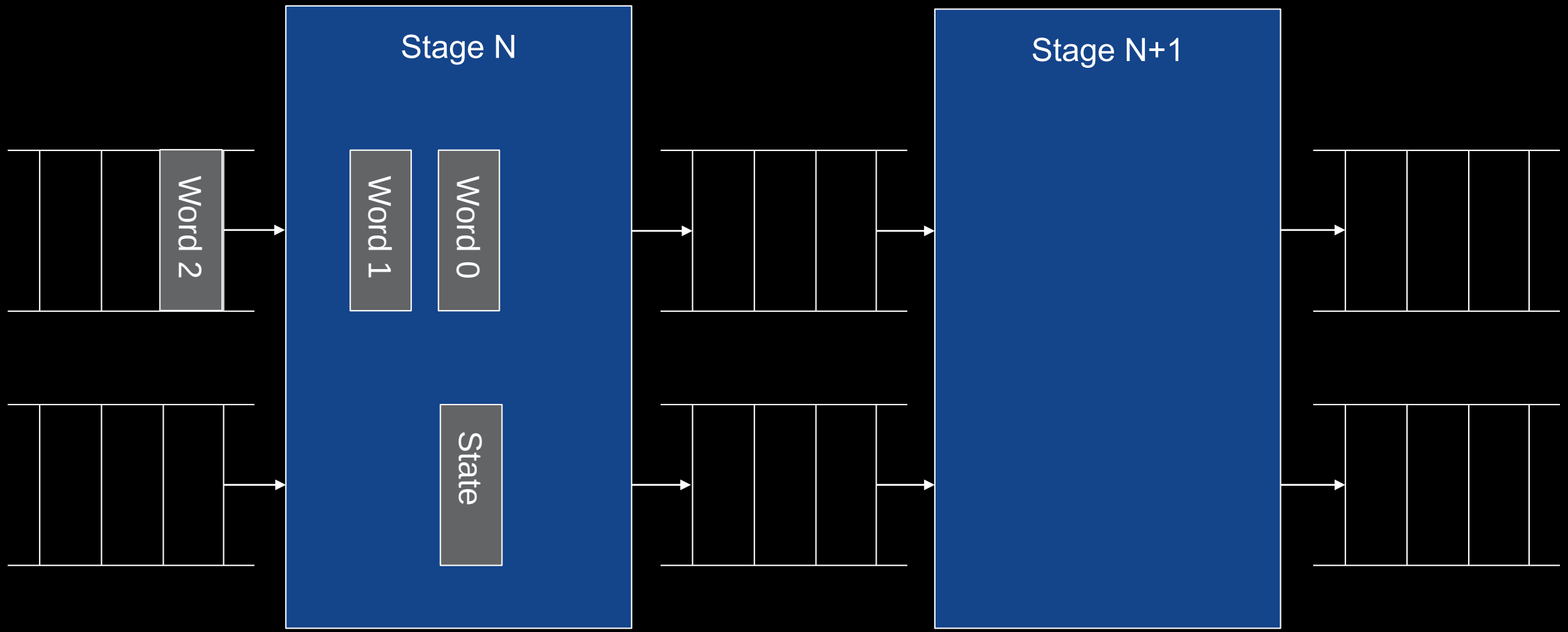
Processing packet words



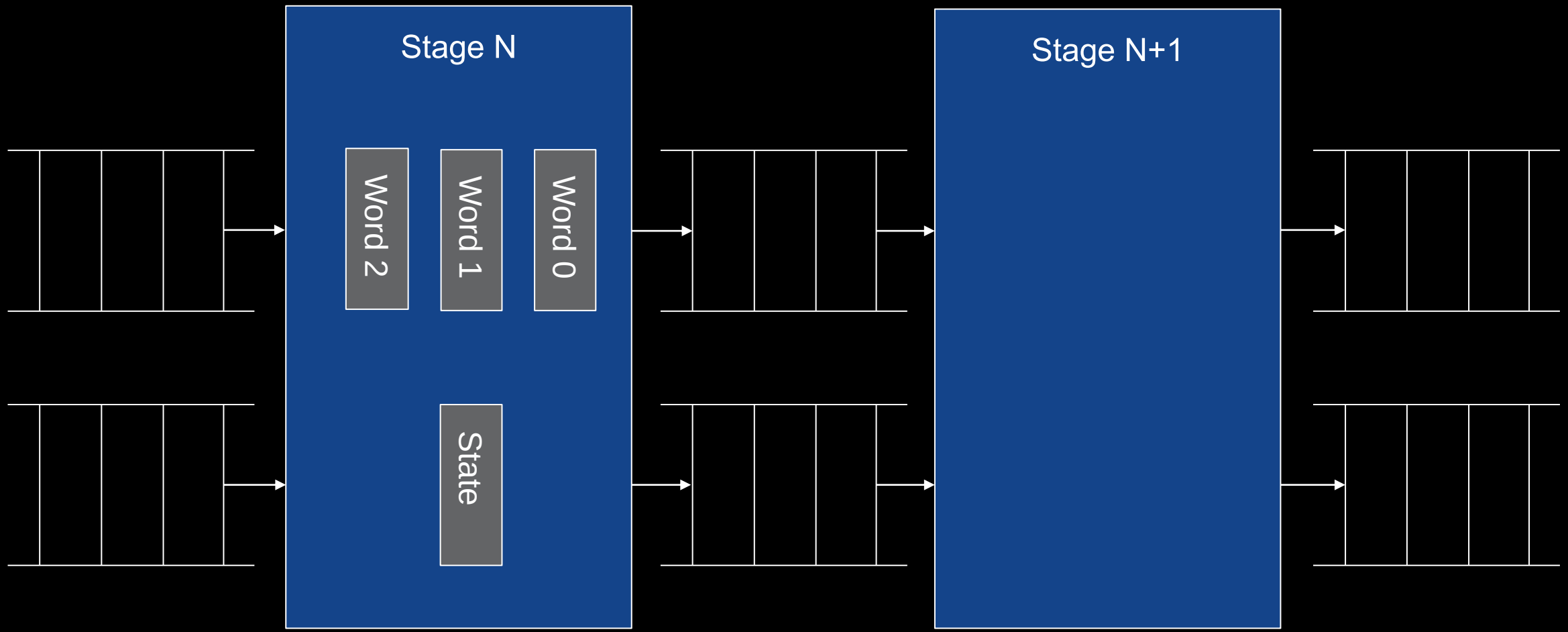
Processing packet words



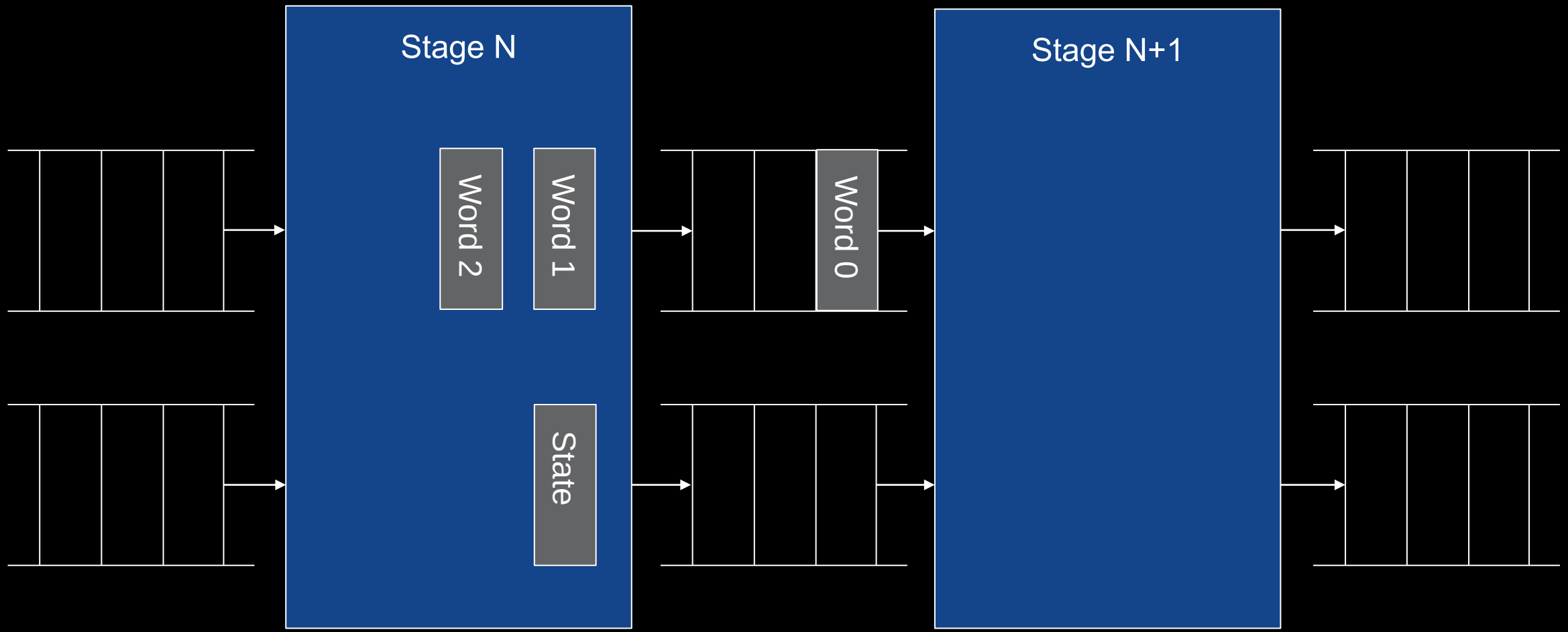
Processing packet words



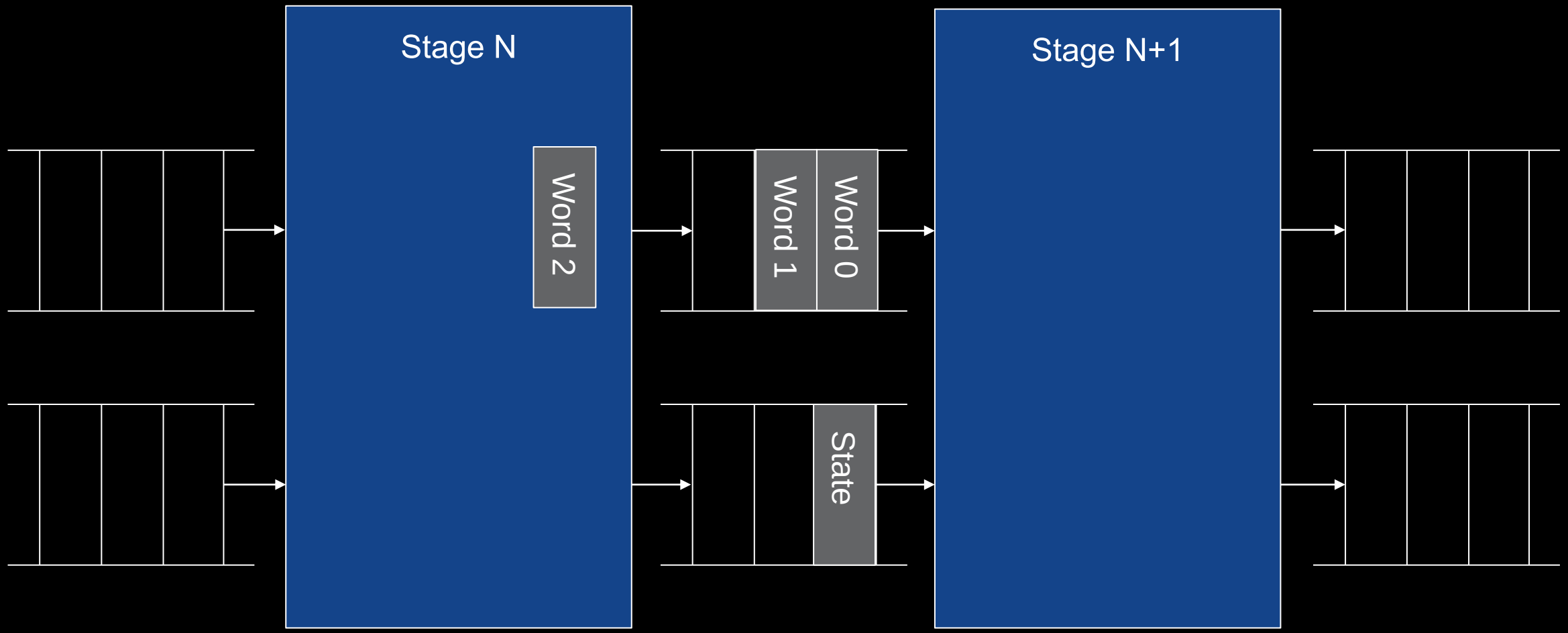
Processing packet words



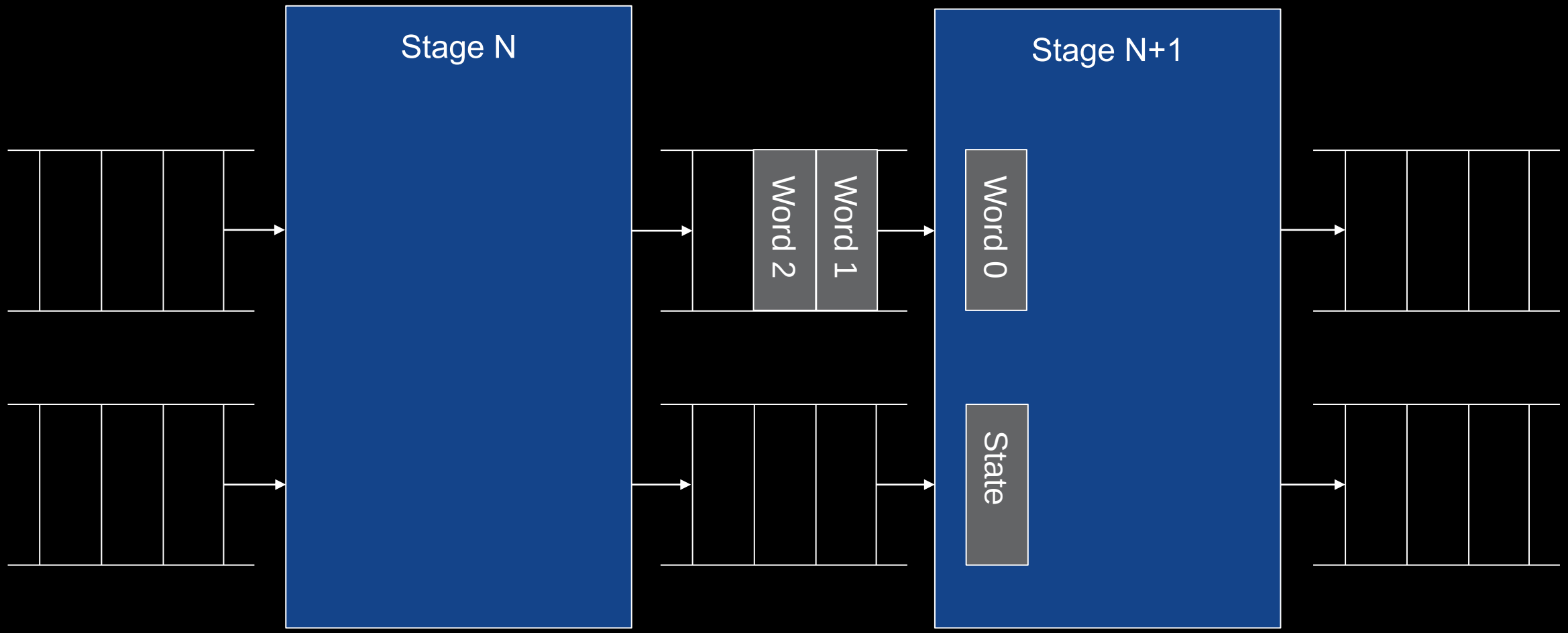
Processing packet words



Processing packet words



Processing packet words



Comparisons with a CPU/NPU based approach

Pros

- Processes many packets in parallel
- Deterministic performance
- Compute resources adapt to the program
- No instruction fetch logic
- No instruction cache
- No branch prediction logic
- No load balancer logic
- No branch penalty
- No load imbalance

Cons

- No instruction cache or branches
- Rarely used code paths occupy FPGA space
- JIT compilation is not feasible
- Uses vendor-specific tools

Nanotube passes

Ebpf2nt - Converts eBPF helper calls into Nanotube API calls

Mem2req - Converts pointer accesses to read/write requests

Lower - Add functions for handling packet metadata

Inline - Inline functions from the previous step

Platform - Adjust packet offsets to account for metadata

Control capsule - Add code to handle control packets

Optreq - Combine similar requests

Converge - Makes Nanotube API calls unconditional

Pipeline - Breaks the pipeline into stages at Nanotube API call sites

Link_taps - Add functions to access packets and maps

Inline_opt - Inline functions from the previous step

HLS printer - Produces HLS C++ output

The ebpf2nt pass

```
int ip_tunnel(struct xdp_md *ctx)
{
  char *data =  (char*)(uint64_t)(ctx->data);
  char *end = (char*)(uint64_t)(ctx->data_end);
  [...]
}
```

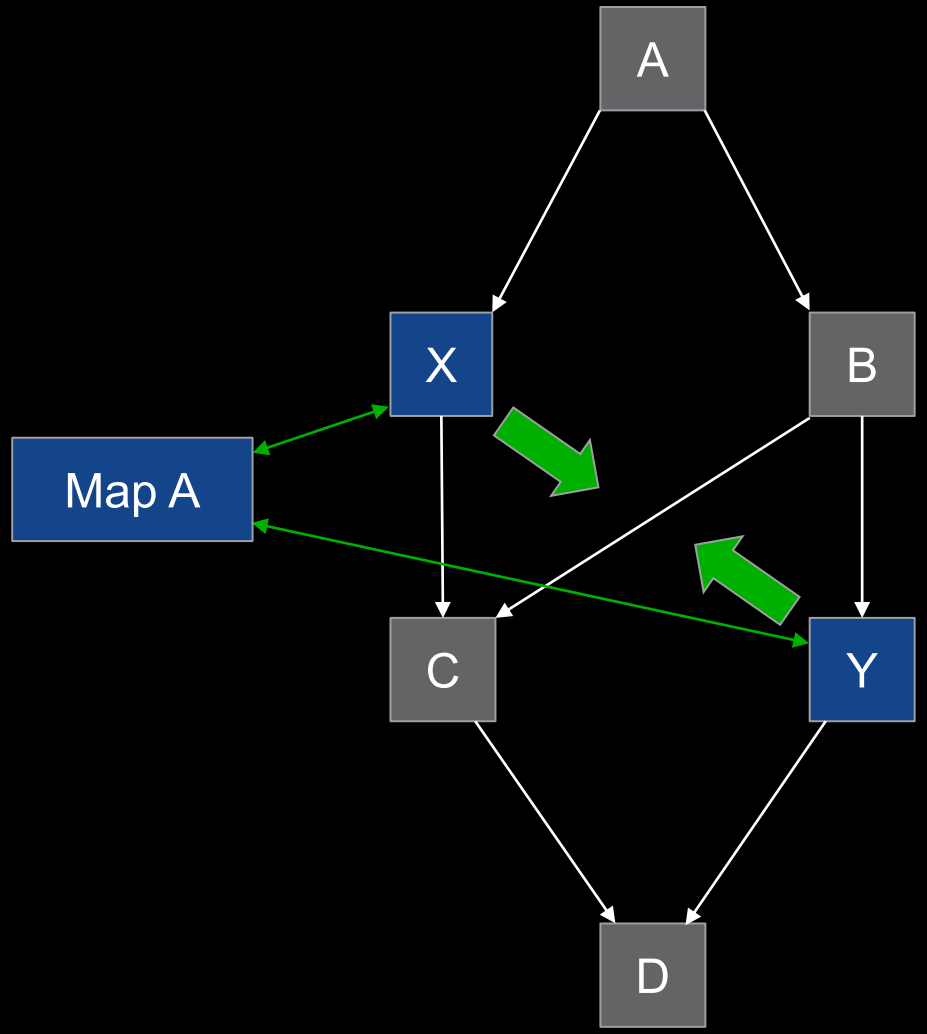
```
int ip_tunnel_nt(struct nanotube_context *nt_ctx,
                 struct nanotube_packet *packet)
{
  char *packet_data =  nanotube_packet_data(packet);
  char *packet_end = nanotube_packet_end(packet);
  [...]
}
```

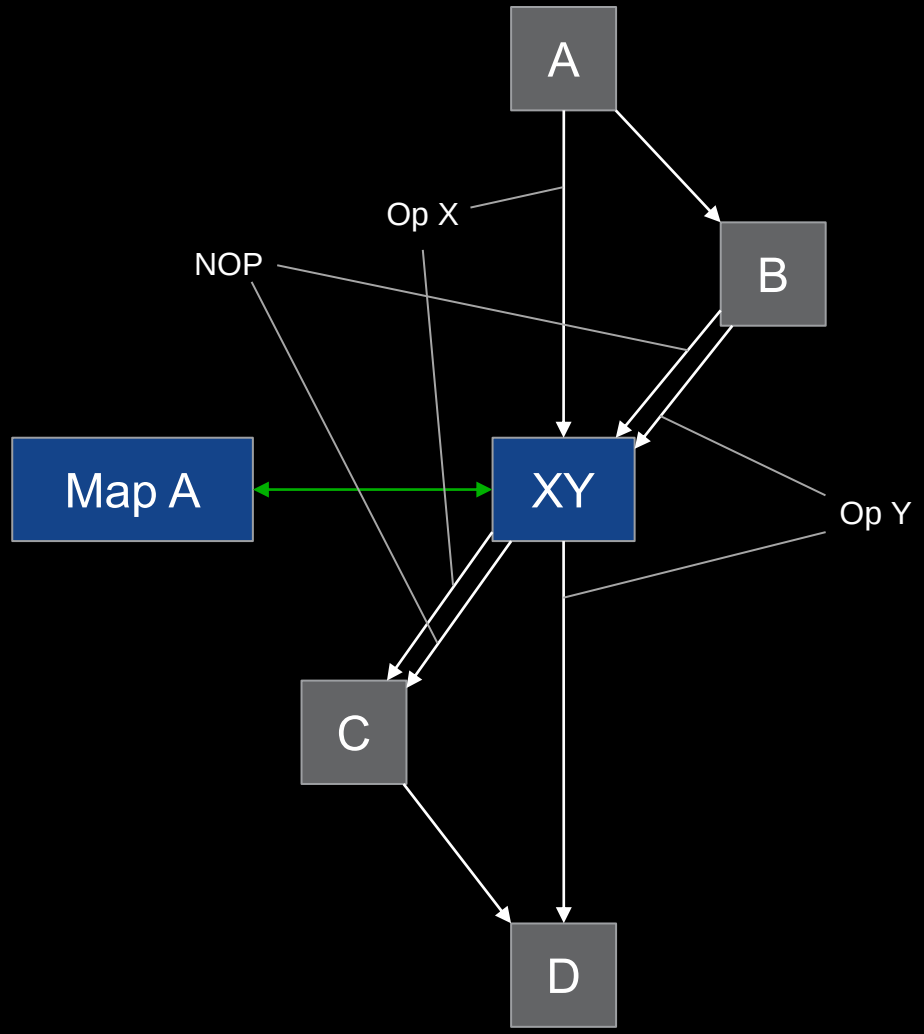
The mem2req pass

```
int ip_tunnel_nt(struct nanotube_context *nt_ctx,
                 struct nanotube_packet *packet)
{
  uint8_t *packet_data = nanotube_packet_data(packet);
  uint8_t *packet_end = nanotube_packet_end(packet);

  if (nanotube_packet_bounded_length(packet,14) < 14)
    return NANOTUBE_PACKET_DROP;

  uint16_t ether_type = *(uint16_t*)(packet_data+12);
  [...]
}
```

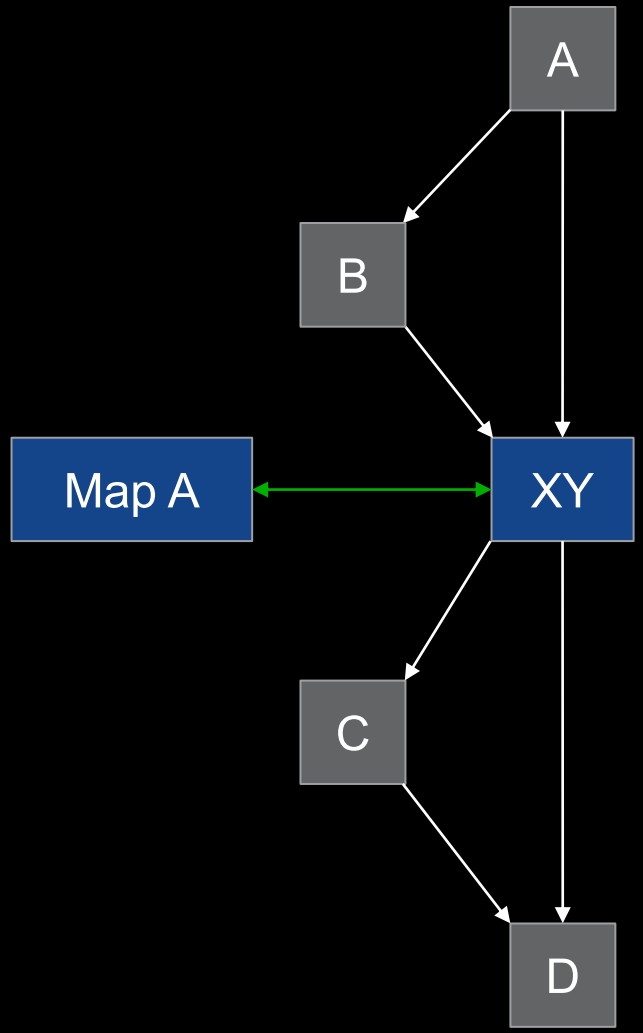
```
int ip_tunnel_nt(struct nanotube_context *nt_ctx,
                 struct nanotube_packet *packet)
{
  if (nanotube_packet_bounded_length(packet,14) < 14)
    return NANOTUBE_PACKET_DROP;

  uint8_t buffer[2];
  nanotube_packet_read(packet, buffer, 12, 2);
  uint16_t ether_type = *(uint16_t*)buffer;
  [...]
}
```

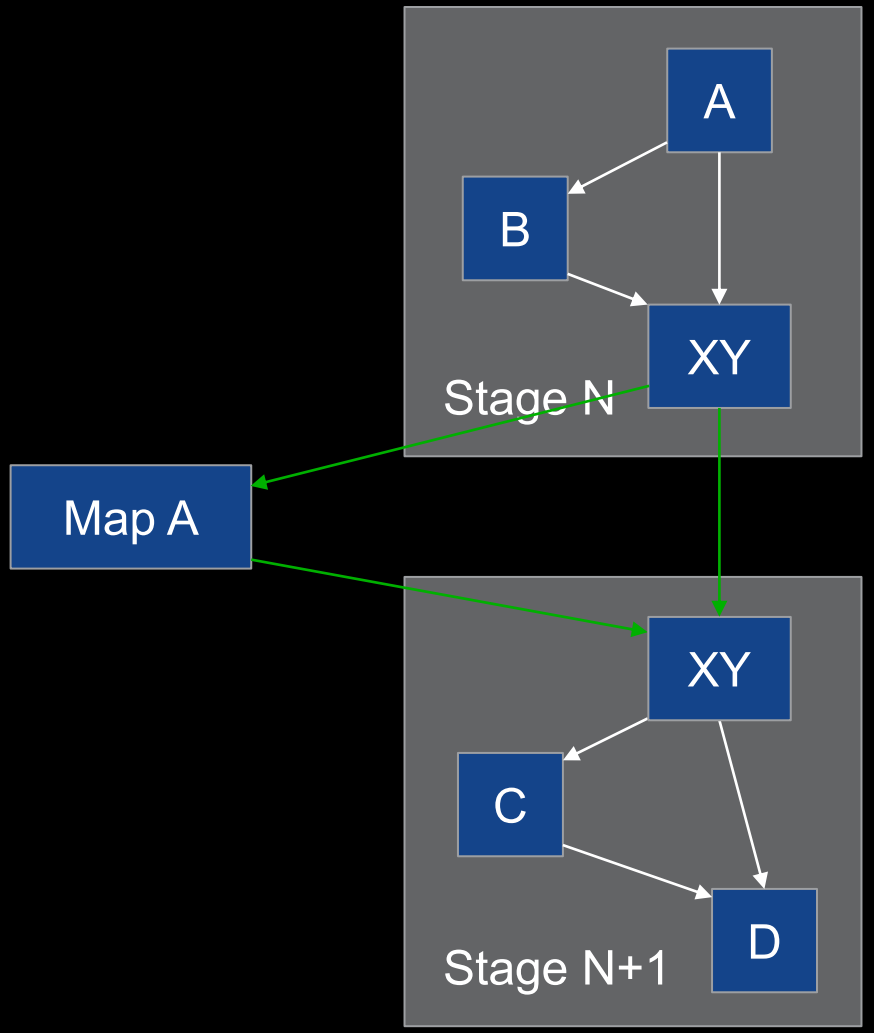
The converge pass





The pipeline pass





Net driver interface

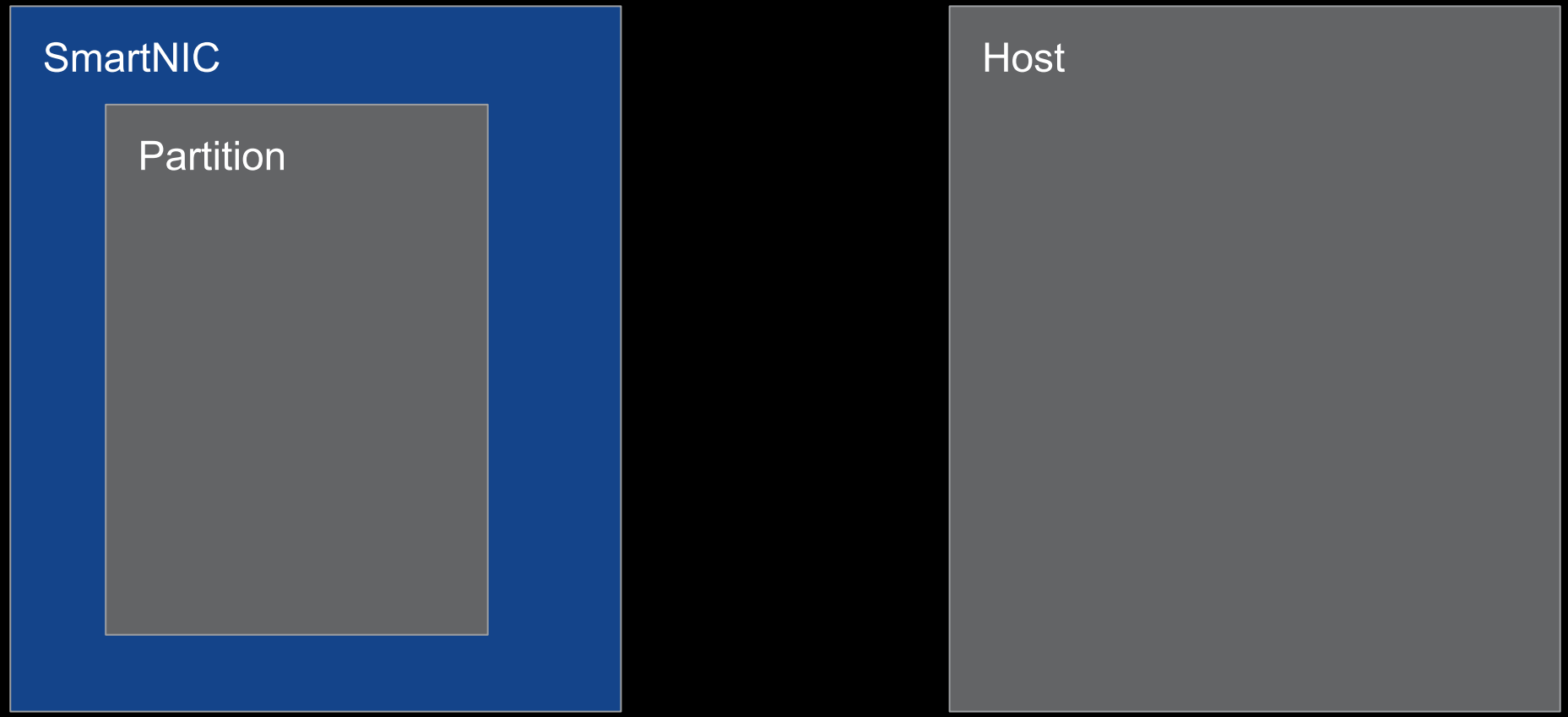
Loading a program

- Create the maps
- Load the BPF byte-code and associate with the maps
- Attach the program to the XDP hardware offload hook

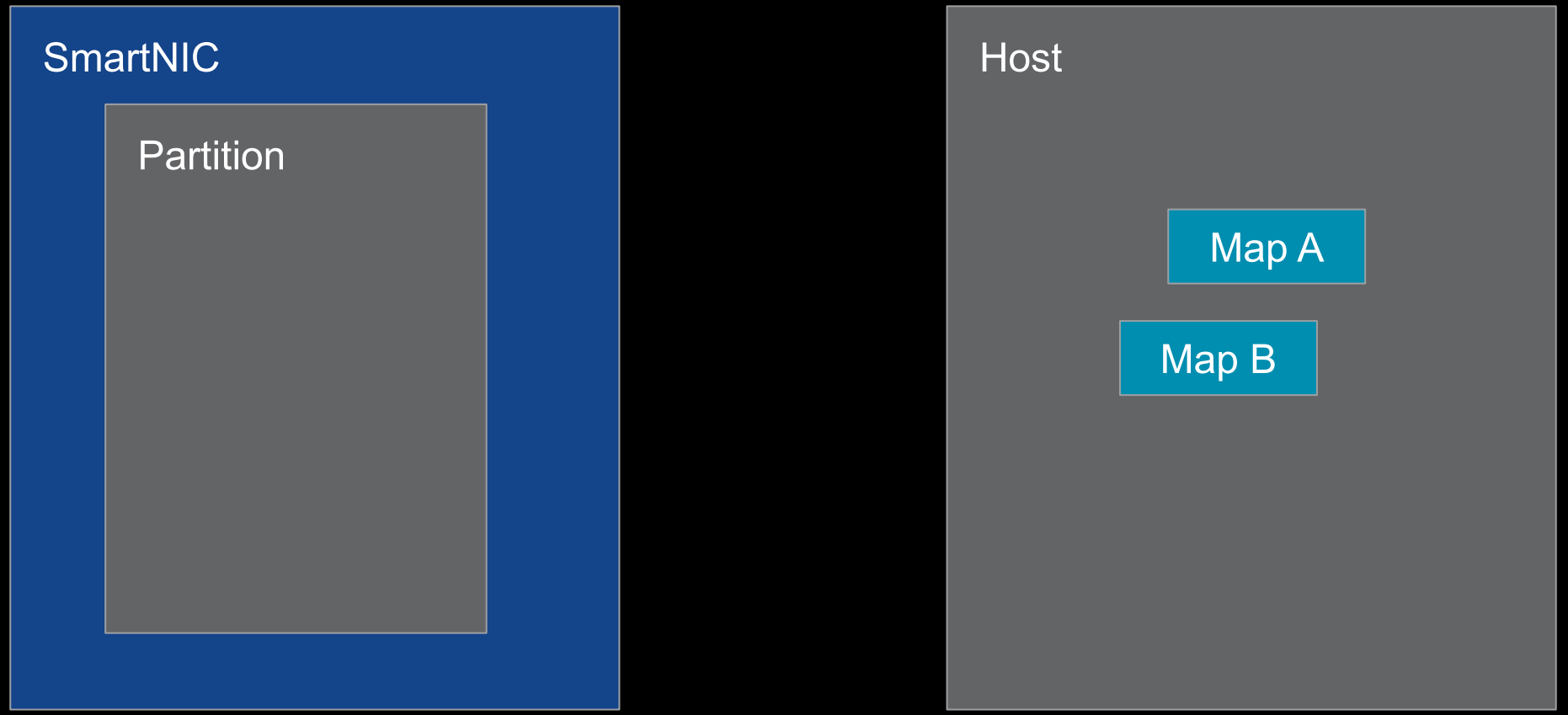
Accessing map entries

- Lookup
- Update
- Delete

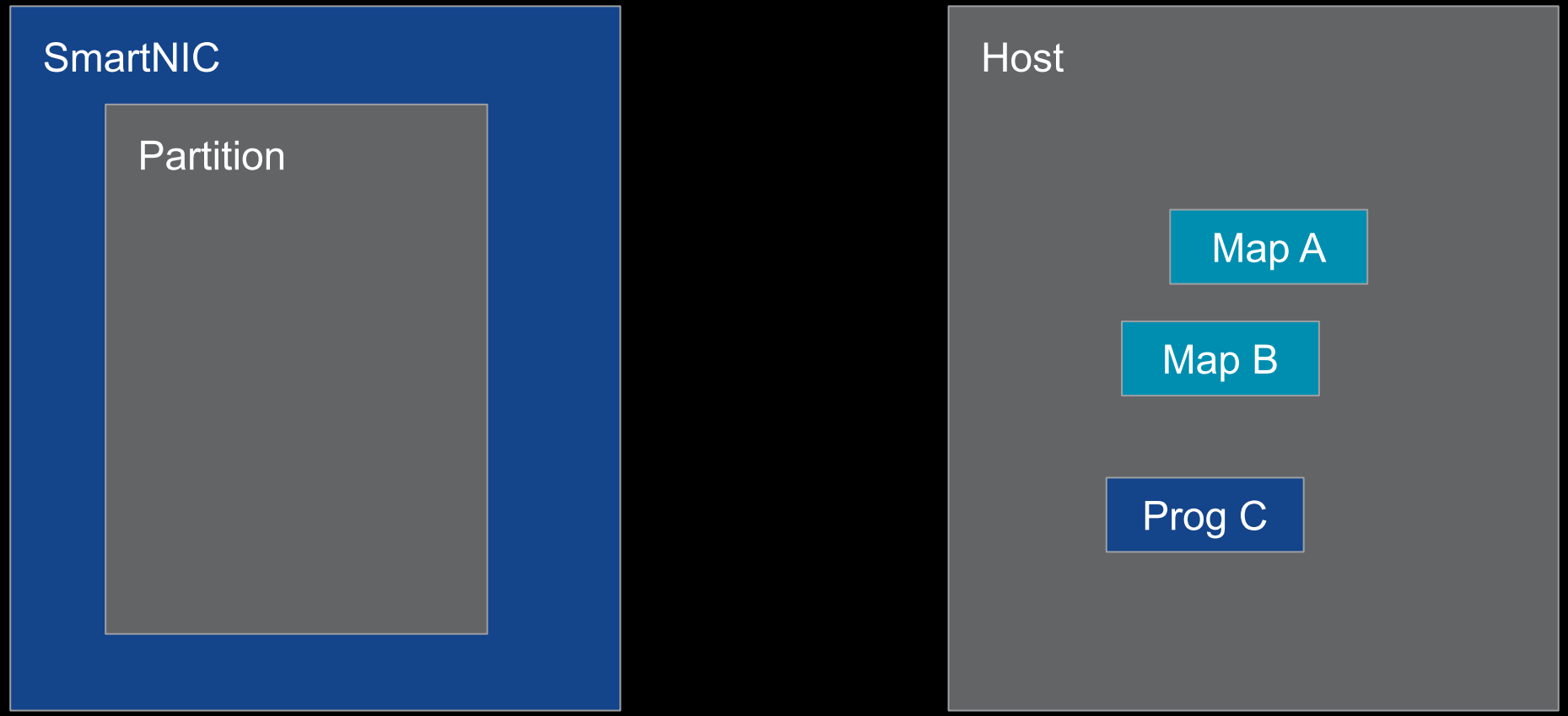
Offloading a program - initial state



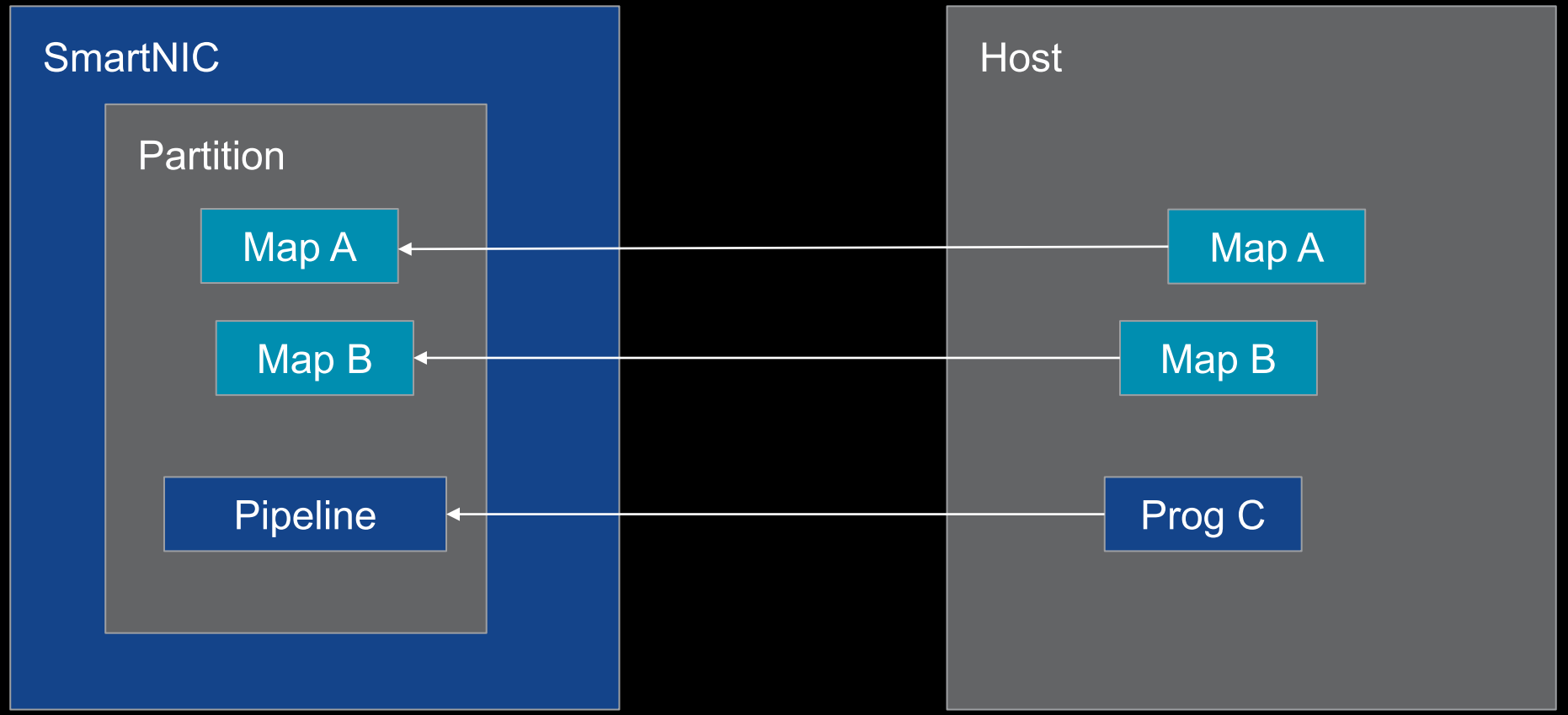
Offloading a program - created maps



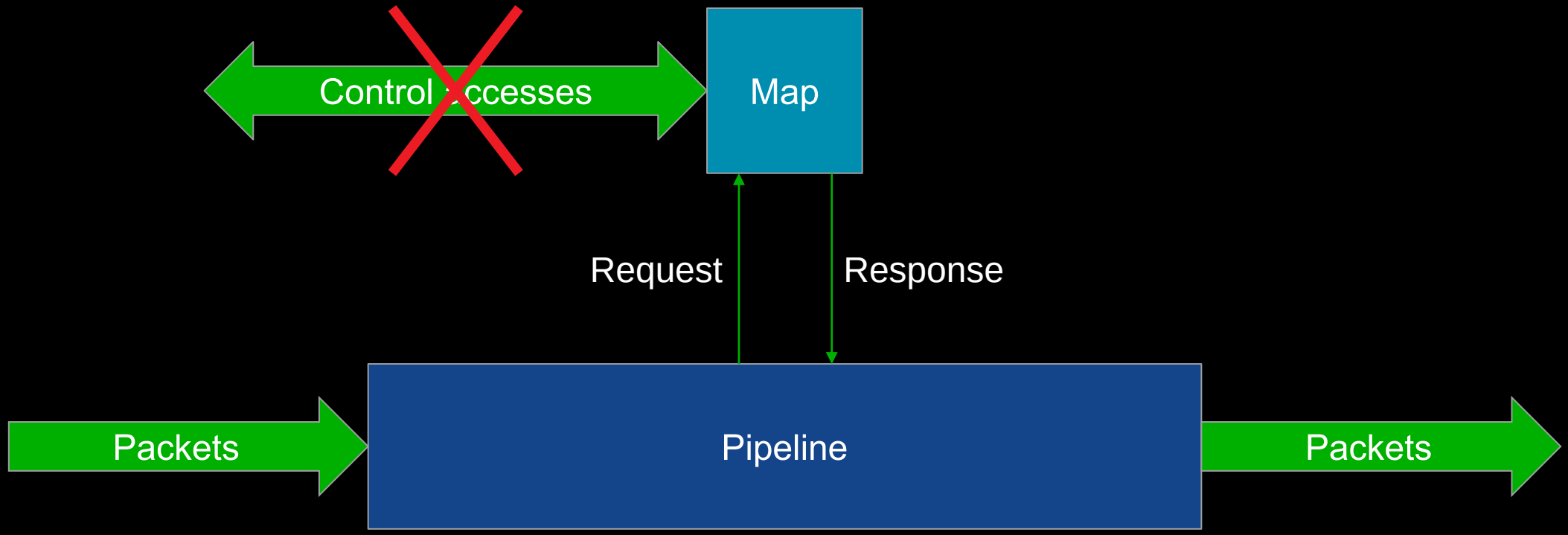
Offloading a program - loaded program



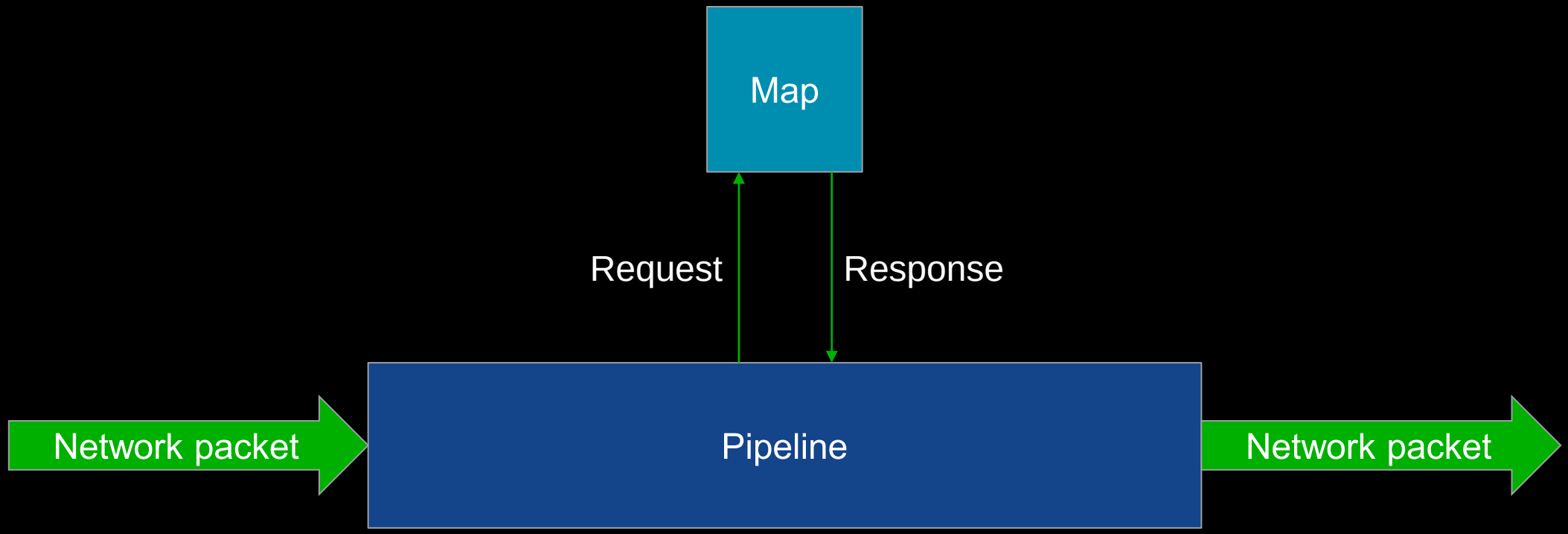
Offloading a program - attached program



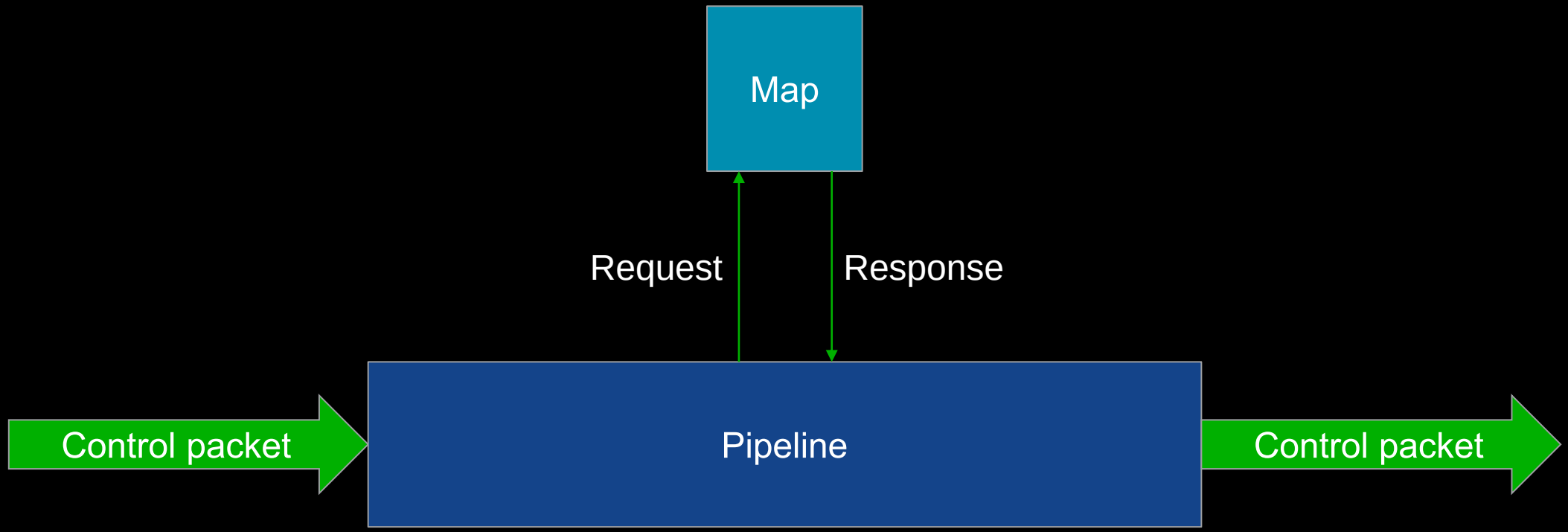
Map accesses from the net driver



Map access for a network packet



Map access for a control packet



Current Status

- Actively being developed
- Working proof of concept compiler
  - Can perform the required structural transformations
  - Tested with the Katran load balancer from Meta
  - Expect to achieve line rate on 100Gbps Ethernet
  - Tested on Alveo™ SN1022 and Alveo™ X3522 SmartNICs
  - Very basic map implementation - max 10 entry array/hash maps
- Net driver changes have not been started

Getting involved

GitHub repository:

https://github.com/Xilinx/nanotube

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