Sketch-based Network Measurement in P4: Identify Heavy Hitter Flows with Software Defined Measurement

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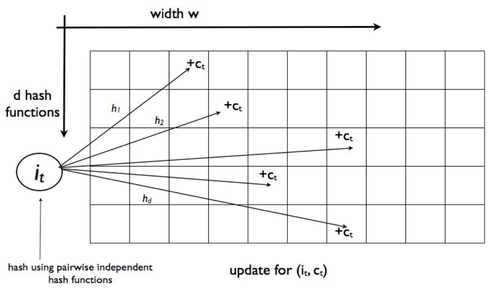
BACKGROUND

- **Basic Problem**: Identify most frequent items in data stream.
- **Count-Minimum (CM) Sketch**: Data structure with precise characterization of the dependence on the input parameters.
- Figure below shows data structure of CM sketch where counter value is updated at location of hash function values for each row.



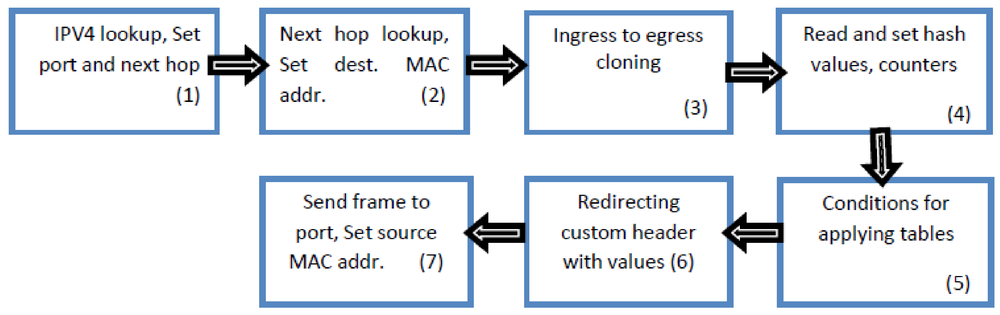
MOTIVATIONS

- **Network Measurement**: Extend P4 with network measurement functionalities for heavy hitters identification.
- **Accuracy**: CM sketch have significant accuracy in keeping summary of different flows in limited storage space.
- **Debugging**: Extend P4 with debugging capability for any application of sketch.

CONTRIBUTIONS

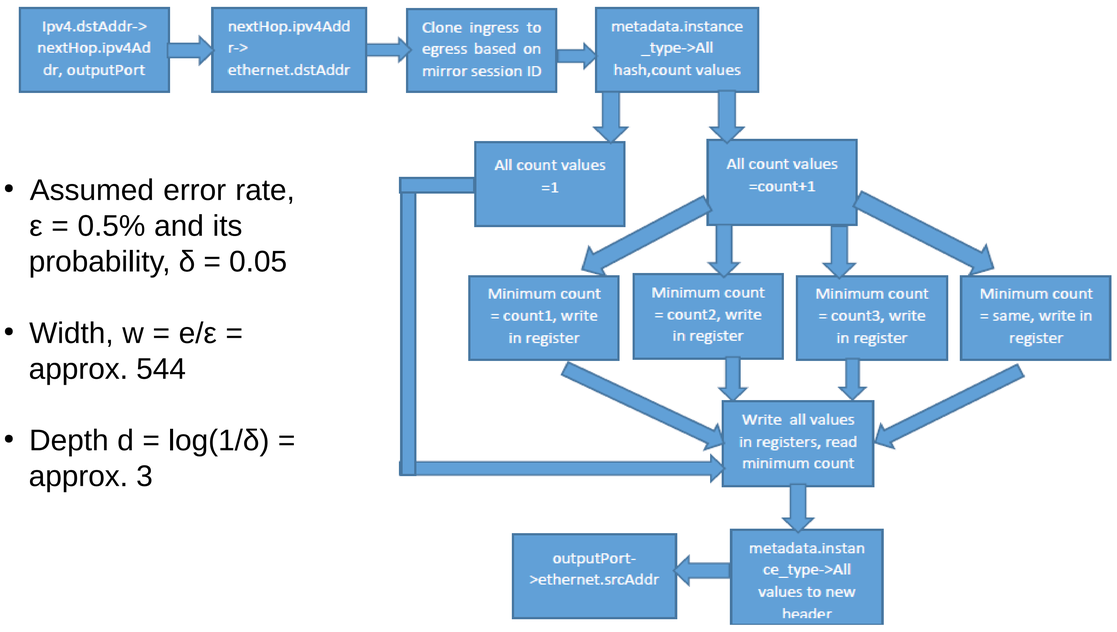
- **Software Define Measurement**: We are the first to demonstrate the design of network measurement sketch in P4, which can be readily leveraged in P4 based network switches and middleboxes
- **Different Category:** This work extends example P4 applications with a different category, which requires substantial metadata processing and registers manipulation.
- **D-packet:** The special debug packet called "D-packet" enhances the debugging support to the existing P4 tool chain, facilitating the design of new applications among the P4 community.

THE DESIGN OF SKETCH



Overview of the design

- Step 1,2 and 7 refer to simple router design which forms our structure.
- Step 3 refers to cloning of packets at ingress which makes second instance of original packet.
- Step 4 refers to setting hash values from hash functions and reading of counter values from hash location of registers, if available.
- Step 5 refers to applying tables depending on conditions like old packet or new packet.
- Step 6 refers to redirecting cloned packet having custom headers with required hash and counter values matched on instance type for cloned packets.

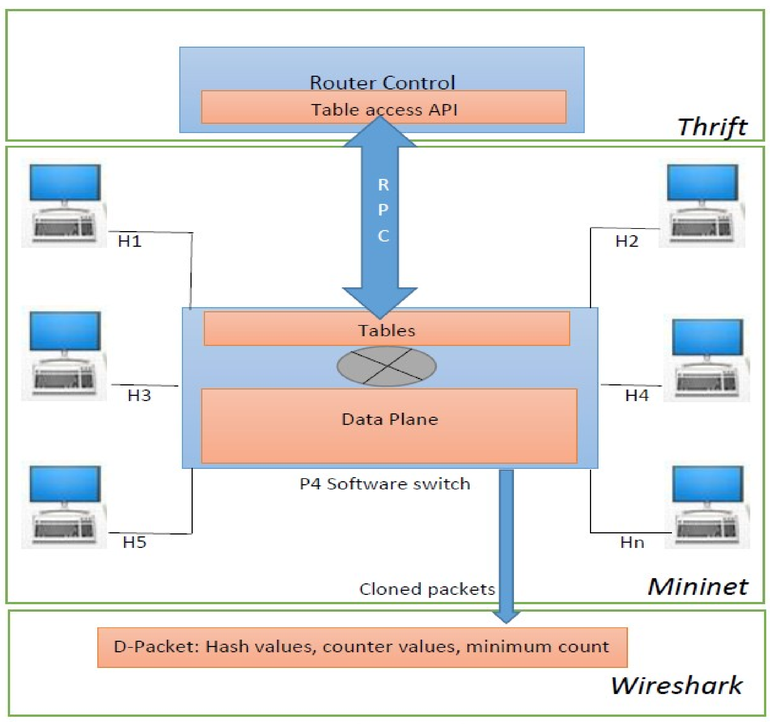


- Assumed error rate, ε = 0.5% and its probability, δ = 0.05
- Width, w = e/ε = approx. 544
- Depth d = log(1/δ) = approx. 3

High level diagram of CM using P4

EXPERIMENTATION AND EVALUATION

- Demo application of P4 for implementing CM sketch is done by passing synthetic traffic through the software switch.
- PINGs sends synthetic traffic of IP addresses. The simple network topology is created by integrating P4 module with mininet environment.



Demonstration environment

- Testing through different number of hosts which pings among themselves through script.

Flow	Src->Dest	No. of packets	C[w1][d1]	C[w2][d2]	C[w3][d3]	Min(C)
F1	h1->h2	14	14	14	14	14
F2	h2->h4	14	14	14	14	14
F3	h1->h3	drop	-	-	-	-
F1	h1->h2	11	25	25	25	25
F4	h4->h6	unknown	-	-	-	-
F2	h2->h4	7	21	21	21	21
F5	h4->h1	8	8	8	8	8
F6	h3->h2	drop	-	-	-	-
F7	h2->h8	unknown	-	-	-	-
F1	h1->h2	11	36	36	36	36
F2	h2->h4	7	28	28	28	28
F5	h4->h1	3	11	11	11	11

Table 1. Demo traffic with w=544, d=3 (host=4)

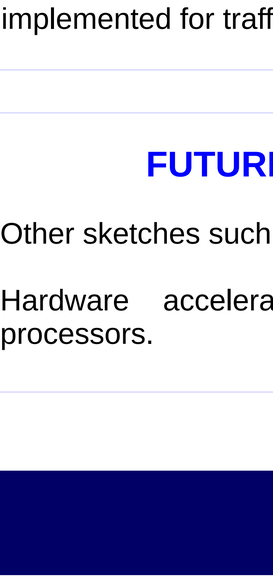
Flow	Src->Dest	No. of packets	C[w1][d1]	C[w2][d2]	C[w3][d3]	C[w4][d4]	Min(C)
F1	h1->h2	14	14	14	14	14	14
F2	h2->h4	8	8	8	8	8	8
F1	h1->h2	17	31	31	31	31	31
F3	h4->h5	14	14	14	14	14	14
F4	h7->h8	5	5	36	36	5	5
F5	h9->h2	14	14	14	14	14	14
F6	h5->h9	15	15	15	15	15	15
F3	h4->h5	8	22	22	22	22	22
F2	h2->h4	9	17	17	17	17	17
F1	h1->h2	20	51	56	56	56	51
F6	h5->h9	9	24	24	24	24	24
F3	h4->h5	21	43	43	43	43	43

Table 2. Demo traffic with w=1000, d=4 (host=9)

Flow	Src->Dest	No. of packets	C[w1][d1]	C[w2][d2]	C[w3][d3]	C[w4][d4]	C[w5][d5]	Min(C)
F1	h1->h2	14	14	14	14	14	14	14
F2	h2->h4	8	8	8	8	8	8	8
F1	h1->h2	17	31	31	31	31	31	31
F3	h4->h5	14	14	14	14	14	14	14
F4	h7->h8	5	5	36	36	36	5	5
F5	h9->h2	14	14	14	14	14	14	14
F6	h5->h9	15	15	15	15	15	15	15
F3	h4->h5	8	22	22	22	22	22	22
F2	h2->h4	9	17	17	17	17	17	17
F1	h1->h2	20	51	56	56	56	51	51
F6	h5->h9	9	24	24	24	24	24	24
F3	h4->h5	21	43	43	43	43	43	43

Table 3. Demo traffic with w=1000, d=5 (host=9)

- Table 1. shows demo traffic evaluation table which correctly gives counter values and also shows drop of non-entry IP address in P4 table.
- Table 2. and Table 3. shows correct minimum count values in fact of hash values conflicts among two flows F1 and F4.



- Simple Parser with 3 headers : Custom header, Ethernet header and IPV4 header.

Simple Sketch Parser

CONCLUSION

- Software defined measurement to identify heavy hitter flows by programming forwarding data plane in P4 through sketch can be done.
- Different sketches and algorithm can be implemented for traffic monitoring.

FUTURE WORK

- Other sketches such as AGMS.
- Hardware acceleration with network processors.