

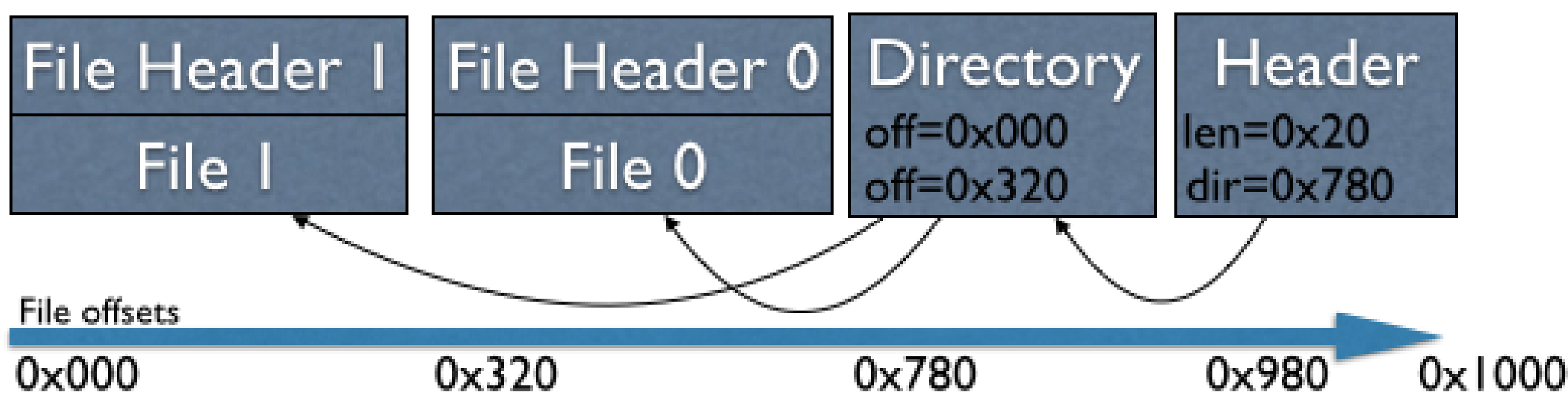
NAIL: A PRACTICAL TOOL FOR PARSING AND GENERATING DATA FORMATS

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Parsing vulnerabilities

- Hand-written parsers introduce bugs.
- Different parsers not equivalent
 - Evasi0n jailbreaks on iOS.
 - PKI layer cake.
 - Android master key.

ZIP: A tricky file format



Case study of ZIP vulnerabilities in the CVE database:

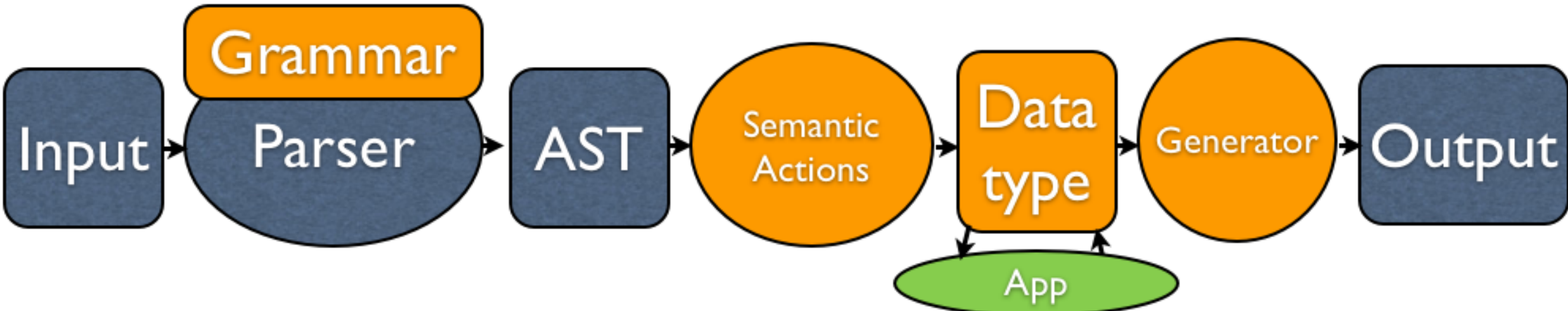
| Classification | Example description | Count |
|---|---|-------|
| Memory corruption | Buffer overflow | 11 |
| Parsing inconsistency | Virus scanners interpret ZIP files incorrectly | 4 |
| Semantic misunderstanding | Weak cryptography used even if user selects AES | 1 |
| Total of all vulnerabilities related to .zip processing | | 16 |

Existing parsers

Automatically generated parsers, such as bison or Hammer are

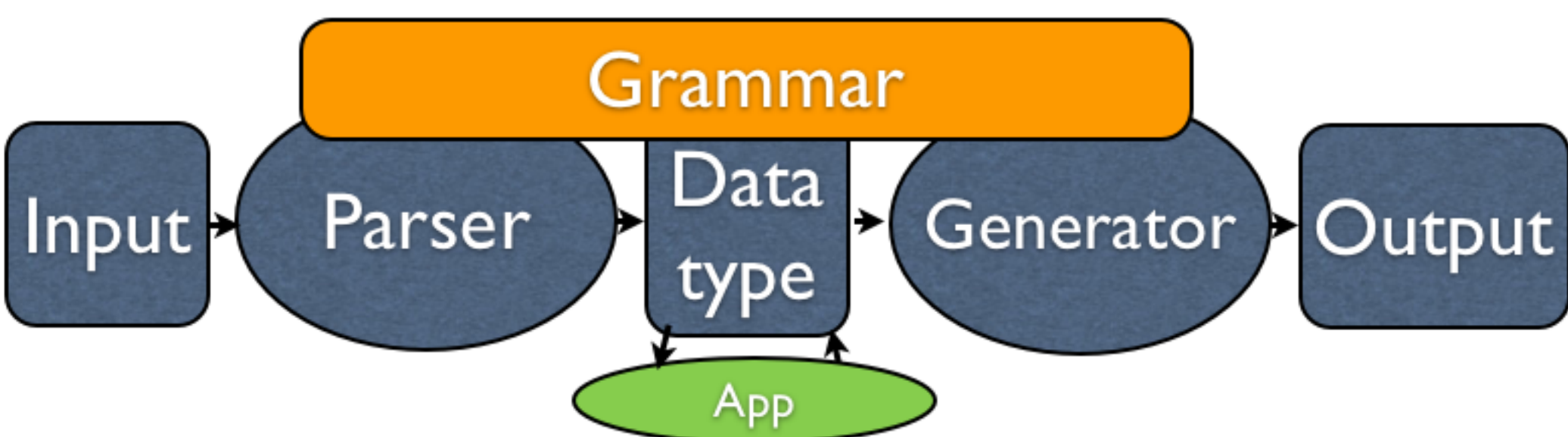
- Immune to classes of bugs (e.g. memory corruption)
- Easier to use
- Re-useable, eliminating parser ambiguities

However, traditional parsers are inconvenient to use, because the programmer has to write all the yellow-colored parts:



Nail

Nail grammars describe both the format and a data type to represent it, an idea introduced by data description languages such as PacketTypes.



Dependent Fields

- Redundant Information in protocol
 - Length field
 - Repeated information
- Confuses application, e.g.:
 - Android master key: Uses local name length for extracting, directory for signature
 - PKI layer cake: Mix implicit (terminator) string length and length field.

Dependent Fields **hide redundant information** and automatically verify and generate it.

Streams and Transformations

- Existing parsers are linear, consuming input front to back.
- Nail grammars feature multiple streams.
- *Transformations* modify and create streams.
- Pair of functions operating on streams and dependent fields.
- Standard library of Transformations enough for many formats.
- Programmer can write their own for complex formats.

Nail Grammar for .ZIP

Nail Grammar

```
zip = { /*simplified and cut for brevity*/
/* Call zip_eod transform to isolate end_directory and contents streams*/
$content, $end_directory transform zip_eod ($current)
/* Parse end_directory stream. The end_of_directory parser takes the
content stream as a parameter */
contents apply $end_directory end_of_directory($contents)
}

end_of_directory($filestream) = { /*Grammar rules can have parameters*/
uint32 = 0x06054b50 /* constant*/
disks uint16 | [0] /* constraint*/
directory_disk uint16 | [0]
@this_records uint16 /*dependent field*/
@total_records uint16
/*The following transform ensures these two fields are always equal*/
transform uint16_depend (@this_records @total_records)
@directory_size uint32 /*These two dependent fields are used by the */
@directory_start uint32/* transformations below to find the directory*/
/*dirstr1 is the the suffic of filestream starting @directory_start*/
$dirstr1 transform offset_u32 ($filestream @directory_start)
/*Another stream with @directory_size bytes starting at that offset*/
$directory_stream transform size_u32 ($dirstr1 @directory_size)
@comment_length uint16 /*Dependent field used with the built in n_of*/
comment n_of @comment_length uint8 /* Variable-length comment*/
files apply $directory_stream n_of @total_records
dir_fileheader($filestream) /*Array of directory entries*/
}

dir_fileheader($filestream) = {
uint32 = 0x02014b50
@compressed_size uint16
@crc32 uint32
@file_name_len uint16
@off uint32
filename n_of @file_name_len uint8
$estream transform offset_u32 ($filestream @off)
contents apply $estream fileentry(@crc32,@compressed_size)
}
```

Excerpt of the generated API

```
struct zip{
end_of_directory contents;
};

struct end_of_directory{
uint16_t disks;
uint16_t directory_disk;/*...*/
struct {
dir_fileheader* elem;
size_t count;
} files;
};

struct dir_fileheader{
struct {
uint8_t*elem;
size_t count;
} filename;
fileentry contents;
};/*...*/

//The programmer calls these generated functions.
int gen_zip(NailArena *tmp_arena,NailStream *out,zip *val);
zip*parse_zip(NailArena *arena,
const uint8_t *data, size_t size);

//The programmers implements these two transformation
//functions and two similar ones for output.
extern int zip_eod_parse(NailArena *tmp,
NailStream *filestream, NailStream *,NailStream *current);
extern int zip_compression_parse(NailArena *tmp,
NailStream *uncomp,NailStream *compressed,uint32_t* size);
```

Evaluation

| Protocol | Grammar | Transform | Application | App LoC | Total LoC | Alternative |
|----------|---------|-----------|-------------|---------|-----------|----------------|
| DNS | 48 | 64 | Server | 186 | 298 | 683 (Hammer) |
| | | | Resolver | 97 | 209 | >3000 (libc) |
| ZIP | 92 | 78 | Extractor | 49 | 219 | 1600(Info-ZIP) |

| | | | | | | |
|----------|----|---|--|--|--|--|
| Ethernet | 16 | 0 | | | | |
| ARP | 10 | 0 | | | | |
| IP | 25 | 0 | | | | |
| UDP | 7 | 0 | | | | |
| ICMP | 5 | 0 | | | | |

Nail and our example applications are available at <https://github.com/jbangert/nail>.