Towards a more expressive and introspectable QEMU command line

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Part I
Things we want from the command line

A simple example

You could run QEMU like this:

```
$ qemu -s -machine usb=on,accel=kvm disk.qcow2
```

Observe:

- Options, with and without arguments, as usual
- Complex argument of the form *key*=*value*,...

A real-world example

```
$ /usr/bin/qemu-system-x86_64 -machine accel=kvm -name boxes-unknown -S -machine pc-i440fx-1.6,accel=kvm,usb=off -cpu \
Penryn -m 3115 -realtime mlock=off -smp 4,sockets=1,cores=4,threads=1 -uuid 8bd53789-adab-484f-8c53-a6df9d5f1dbf -no-u\
ser-config -nodefaults -chardev socket,id=charmonitor,path=/home/guillaume/.config/libvirt/qemu/lib/boxes-unknown.moni\
tor,server,nowait -mon chardev=charmonitor,id=monitor,mode=control -rtc base=utc,driftfix=slew -global kvm-pit.lost_ti\
ck_policy=discard -no-shutdown -global PIIX4_PM.disable_s3=1 -global PIIX4_PM.disable_s4=1 -boot strict=on -device ich\
9-usb-ehci1,id=usb,bus=pci.0,addr=0x5.0x7 -device ich9-usb-uhci1,masterbus=usb.0,firstport=0,bus=pci.0,multifunction=o\
n,addr=0x5 -device ich9-usb-uhci2,masterbus=usb.0,firstport=2,bus=pci.0,addr=0x5.0x1-device ich9-usb-uhci3,masterbus=u\
sb.0,firstport=4,bus=pci.0,addr=0x5.0x2 -device virtio-serial-pci,id=virtio-serial0,bus=pci.0,addr=0x6 -device usb-cci\
d,id=ccid0 -drive file=/home/guillaume/.local/share/gnome-boxes/images/boxes-unknown,if=none,id=drive-ide0-0-0,format=\
qcow2,cache=none -device ide-hd,bus=ide.0,unit=0,drive=drive-ide0-0-0,id=ide0-0-0,bootindex=1 -drive if=none,id=drive-\
ide0-1-0,readonly=on,format=raw -device ide-cd,bus=ide.1,unit=0,drive=drive-ide0-1-0,id=ide0-1-0 -netdev tap,fd=23,id=\
hostnet0 -device rtl8139,netdev=hostnet0,id=net0,mac=52:54:00:db:56:54,bus=pci.0,addr=0x3 -chardev spicevmc,id=charsma\
rtcard0,name=smartcard -device ccid-card-passthru,chardev=charsmartcard0,id=smartcard0,bus=ccid0.0 -chardev pty,id=cha\
rserial0 -device isa-serial,chardev=charserial0,id=serial0 -chardev spicevmc,id=charchannel0,name=vdagent -device virt\
serialport,bus=virtio-serial0.0,nr=1,chardev=charchannel0,id=channel0,name=com.redhat.spice.0 -device usb-tablet,id=in\
put0 -spice port=5901,addr=127.0.0.1,disable-ticketing,image-compression=off,seamless-migration=on -device qxl-vga,id=\
video0,ram_size=67108864,vram_size=67108864,vgamem_mb=16,bus=pci.0,addr=0x2 -device AC97,id=sound0,bus=pci.0,addr=0x4 \
-chardev spicevmc,id=charredir0,name=usbredir -device usb-redir,chardev=charredir0,id=redir0 -chardev spicevmc,id=char\
redir1,name=usbredir -device usb-redir,chardev=charredir1,id=redir1 -chardev spicevmc,id=charredir2,name=usbredir -dev\
ice usb-redir,chardev=charredir2,id=redir2 -chardev spicevmc,id=charredir3,name=usbredir -device usb-redir,chardev=cha\
rredir3,id=redir3 -incoming fd:20 -device virtio-balloon-pci,id=balloon0,bus=pci.0,addr=0x7 -msg timestamp=on
```

We clearly push CLI beyond its intended use...

Wanted: config files

Some use cases are better served by config files:

```
$ qemu-system-x86_64 -readconfig vm1.cfg
```

Everything CLI should also work in config files

Another config interface: QMP

QEMU Monitor Protocol (QMP):

```
QMP> {"execute": "blockdev-add",
      "arguments": {"node-name": "node1",
                    "driver": "file",
                    "filename": "tmp.img"}}
{"return": {}}
```

Observe:

- Commands and responses are JSON objects

Why *two* config interfaces?

Run-time reconfiguration must use QMP

Much initial configuration uses CLI, because...

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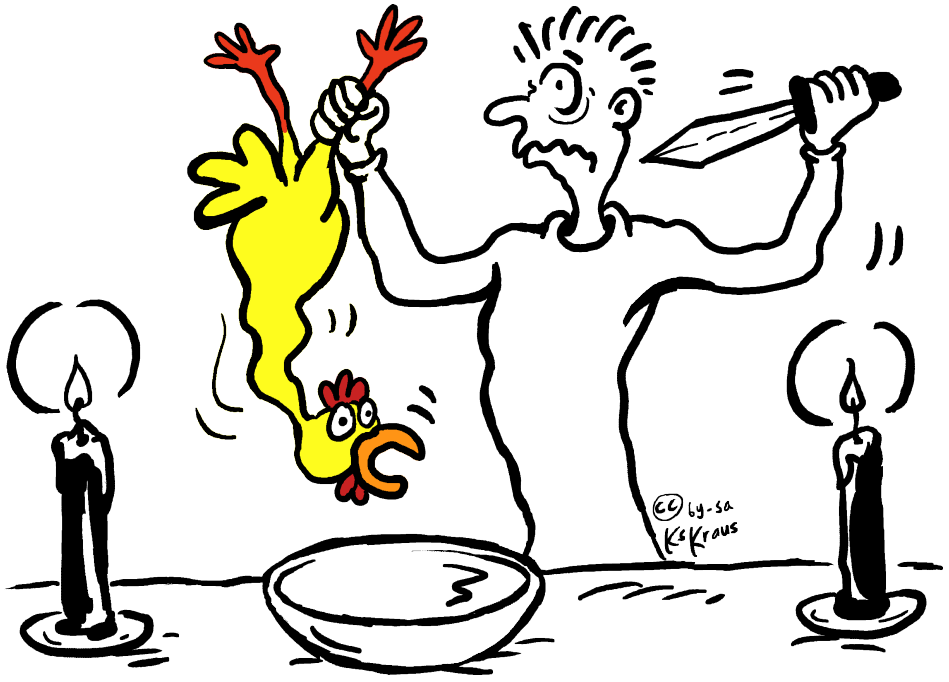

- we've always done it this way (and we turn like a tanker)
- we're *devoted* to backward compatibility

Wanted: equality

Some configuration is needed both in CLI and QMP
(e.g. `-chardev` & `chardev-add`, `-object` & `object-add`)

Our infrastucture should support this:

- CLI and QMP need to be equally expressive
  - QMP needs to express CLI's *key*=*value*,...
  - CLI needs to express QMP's JSON objects

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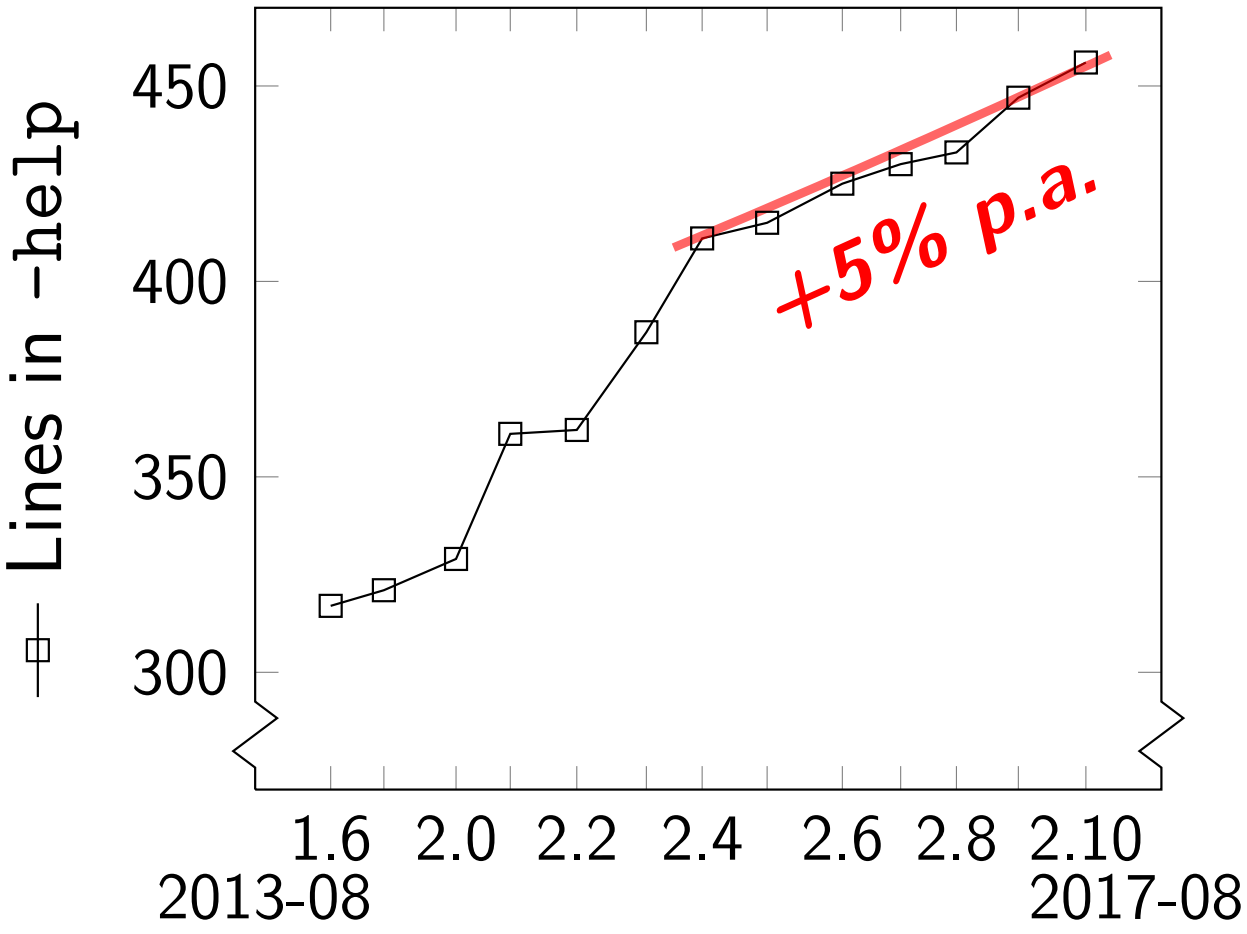
Our infrastucture should support this:

- CLI and QMP need to be equally expressive
  - QMP needs to express CLI's *key*=*value*,...
  - CLI needs to express QMP's JSON objects
- Want to drive single C interface with equal ease

CLI evolves constantly



Wanted: interface introspection

Programs interfacing with QEMU need to know:

- What options are available?

  Example: does this QEMU support `-blockdev`?
- What keys does an option support?

  Example: does `-spice` support `unix`)?
- What values does a key support?

  Example: does `-blockdev` support `driver=gluster`?

⇝ CLI needs to support introspection

Part II
Are these needs met? (TLDR: nope)

CLI option definition

Options are defined like this:

```
DEF("msg", HAS_ARG, QEMU_OPTION_msg,
    "-msg timestamp[=on|off]\n"
    "       change the format of messages\n"
    "       on|off controls leading timestamps\n",
    QEMU_ARCH_ALL)
STEXI
@item -msg timestamp[=on|off]
@findex -msg
prepend a timestamp to each log message.
ETEXI
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Option -msg, has mandatory argument

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Text for -help

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Text for user manual

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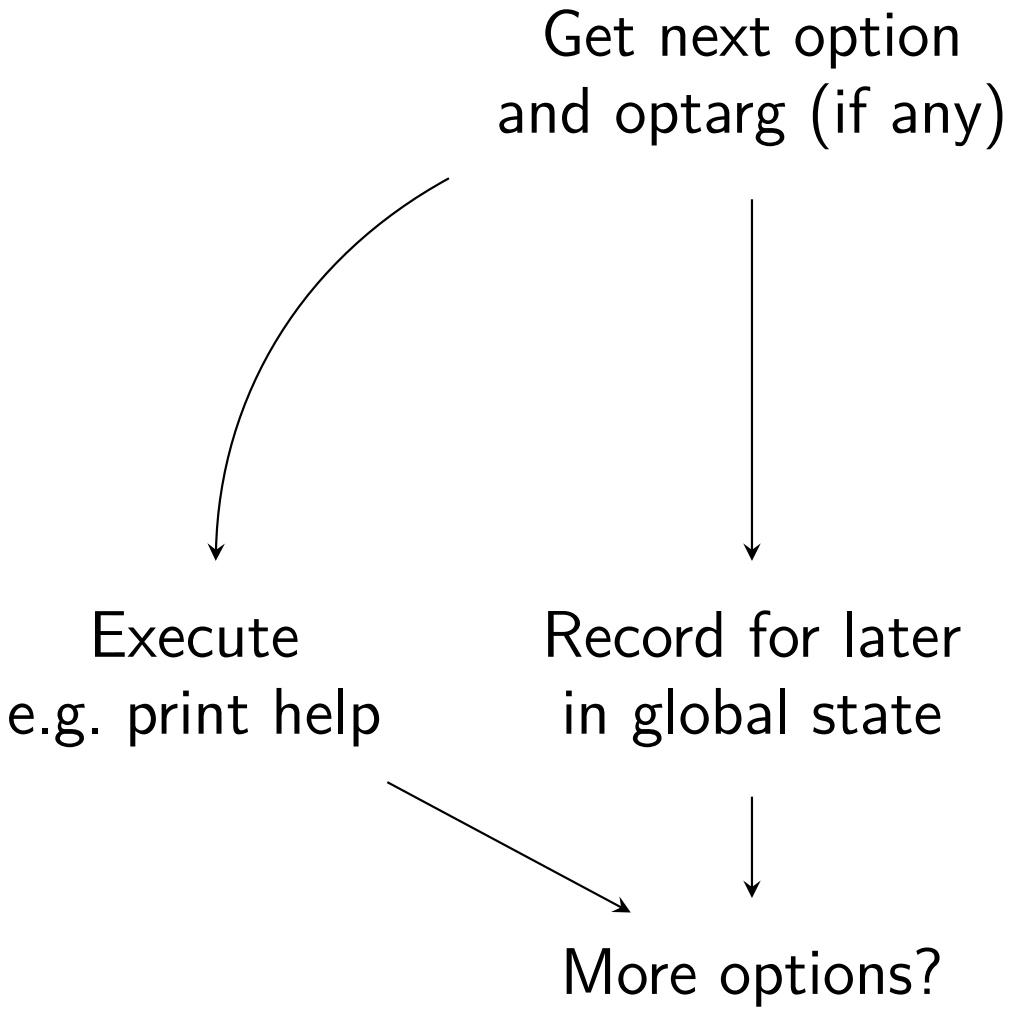
Optarg format in help and manual text, but not in code

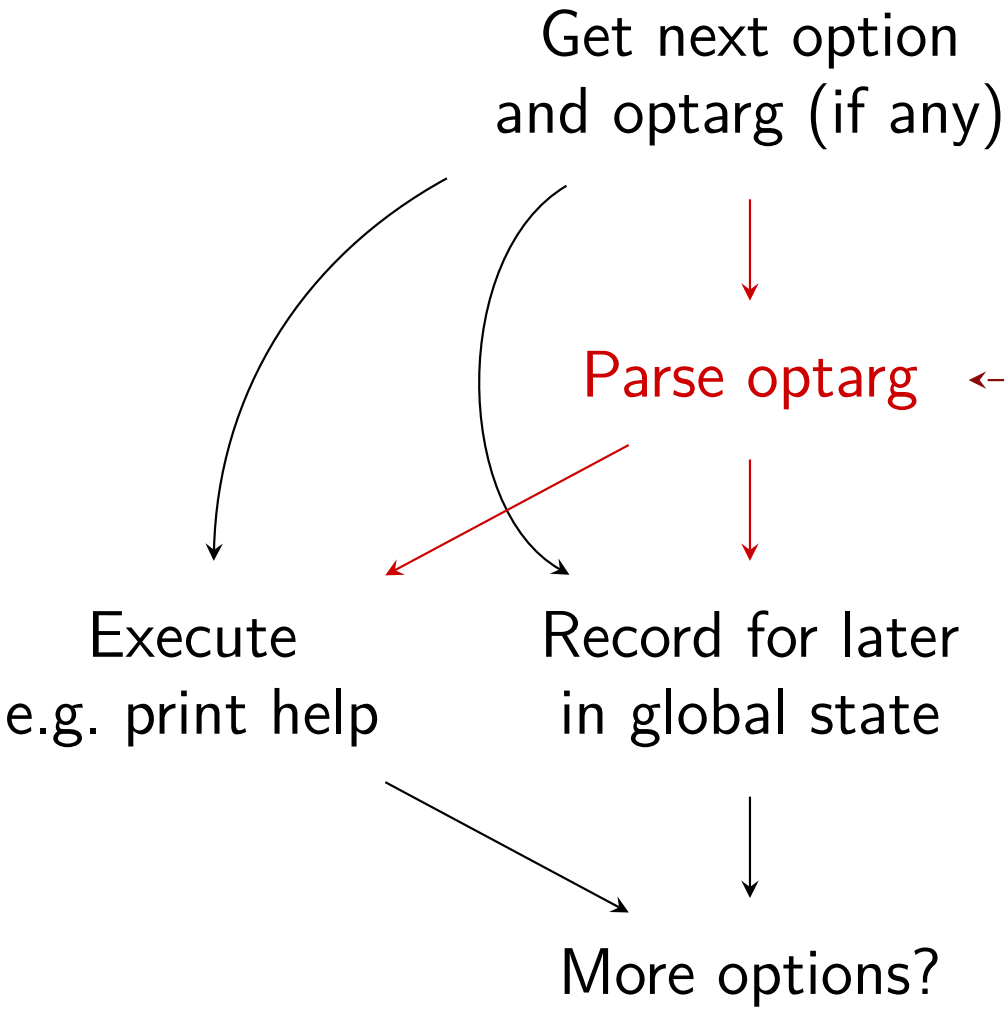
How we parse CLI



Simple optarg

`-help`, `-hda` *FILE*

How we parse CLI

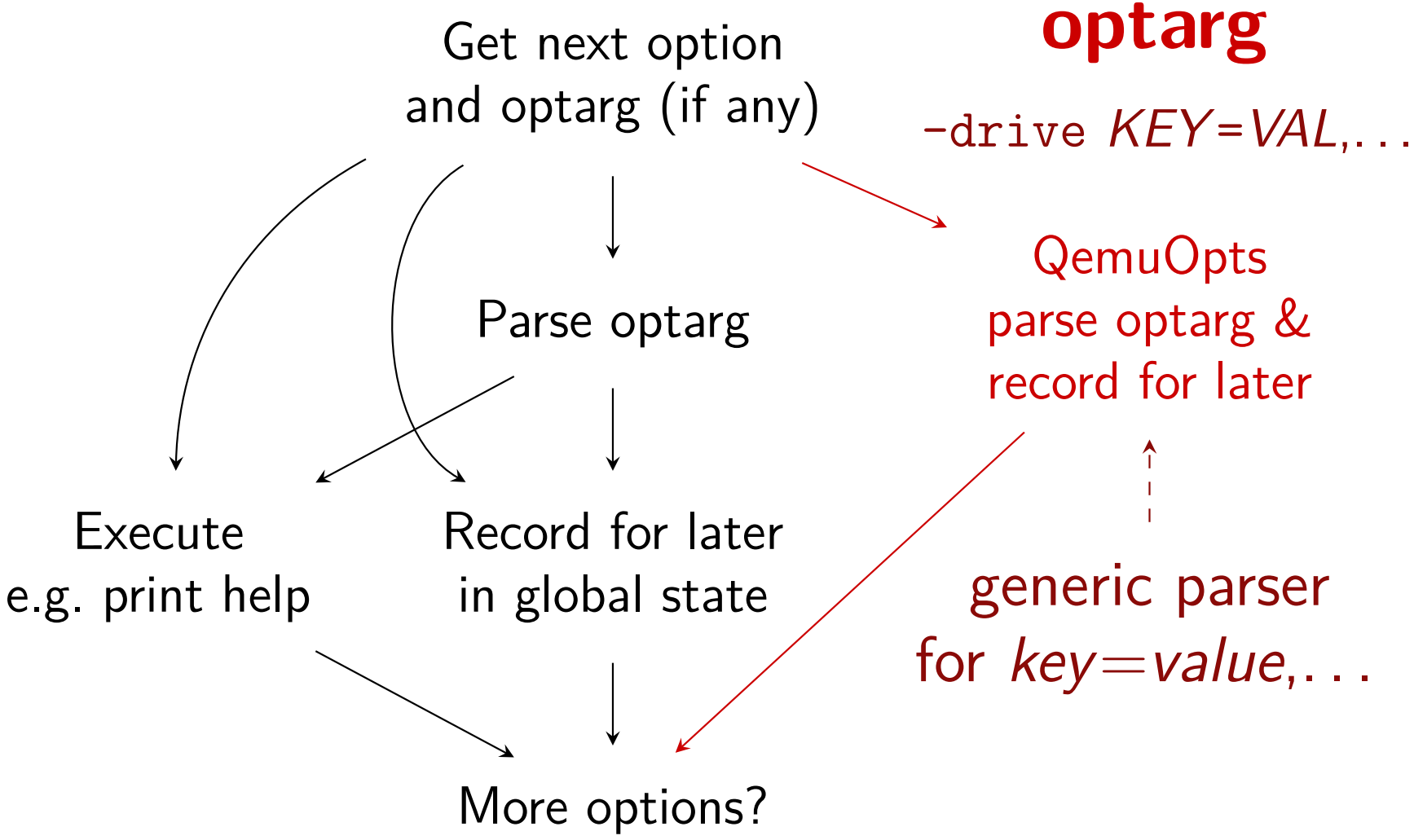


Complex optarg

`-cpu` *CPU*,[-+]*FLAG*,...

20+ ad hoc parsers

How we parse CLI



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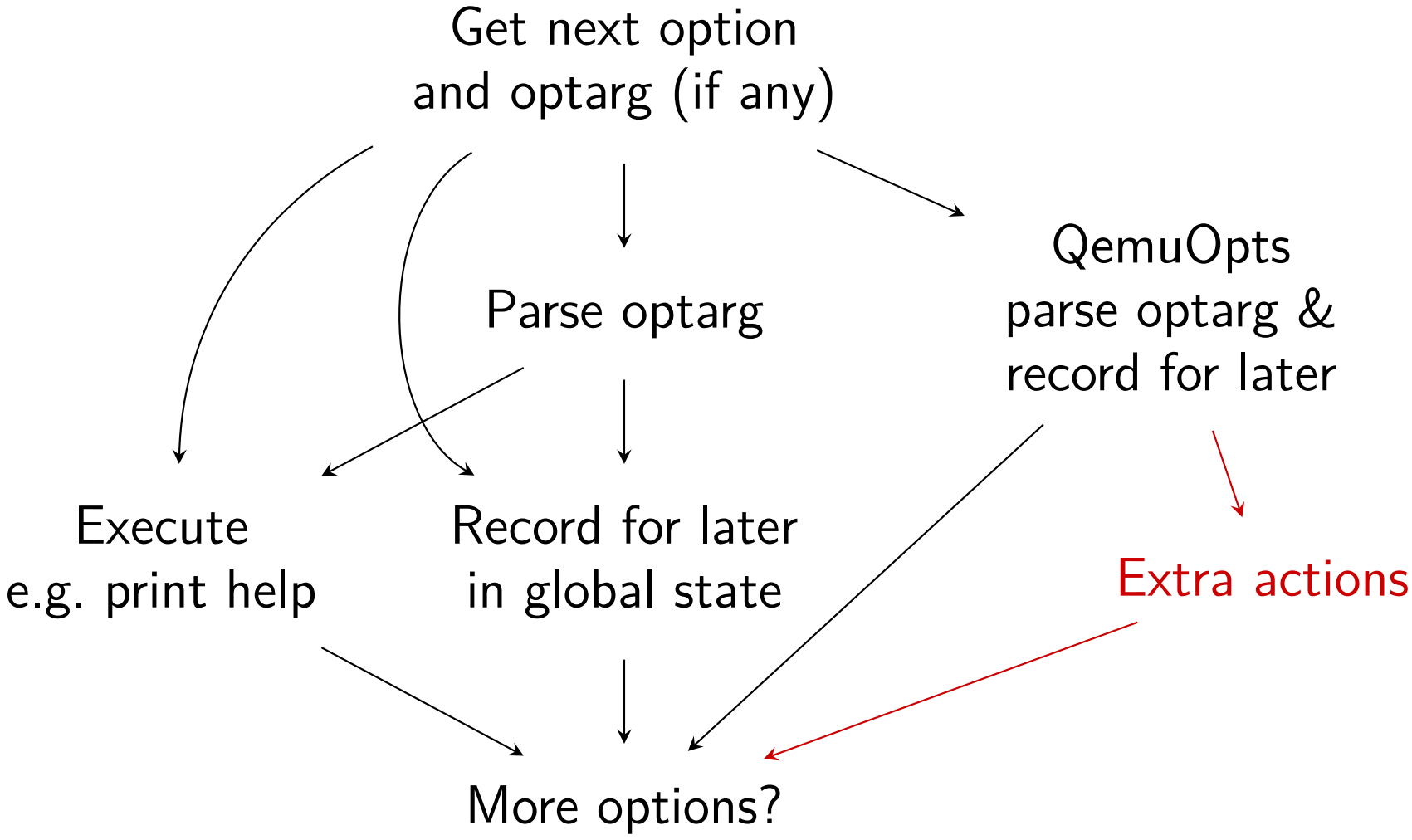

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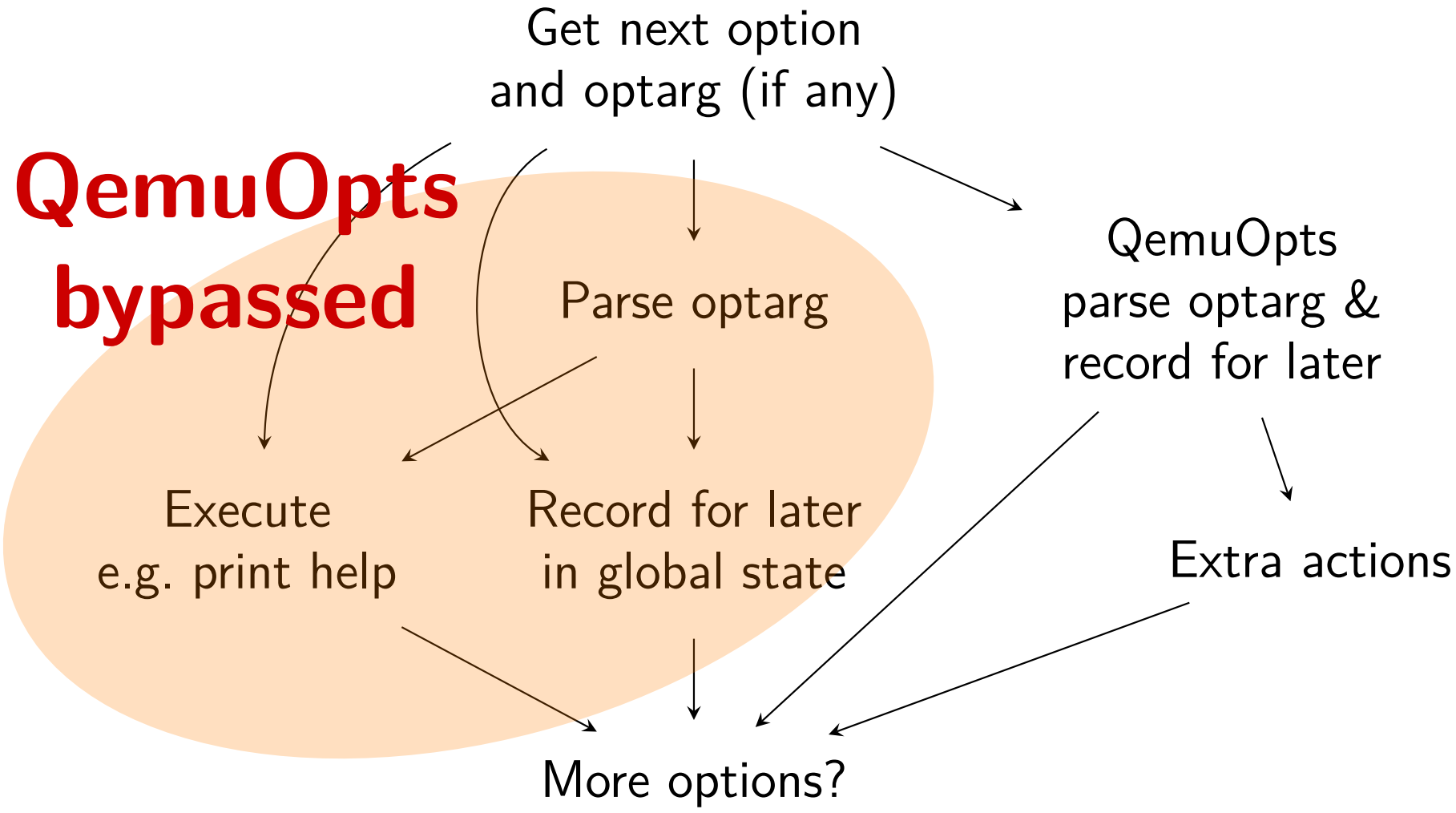

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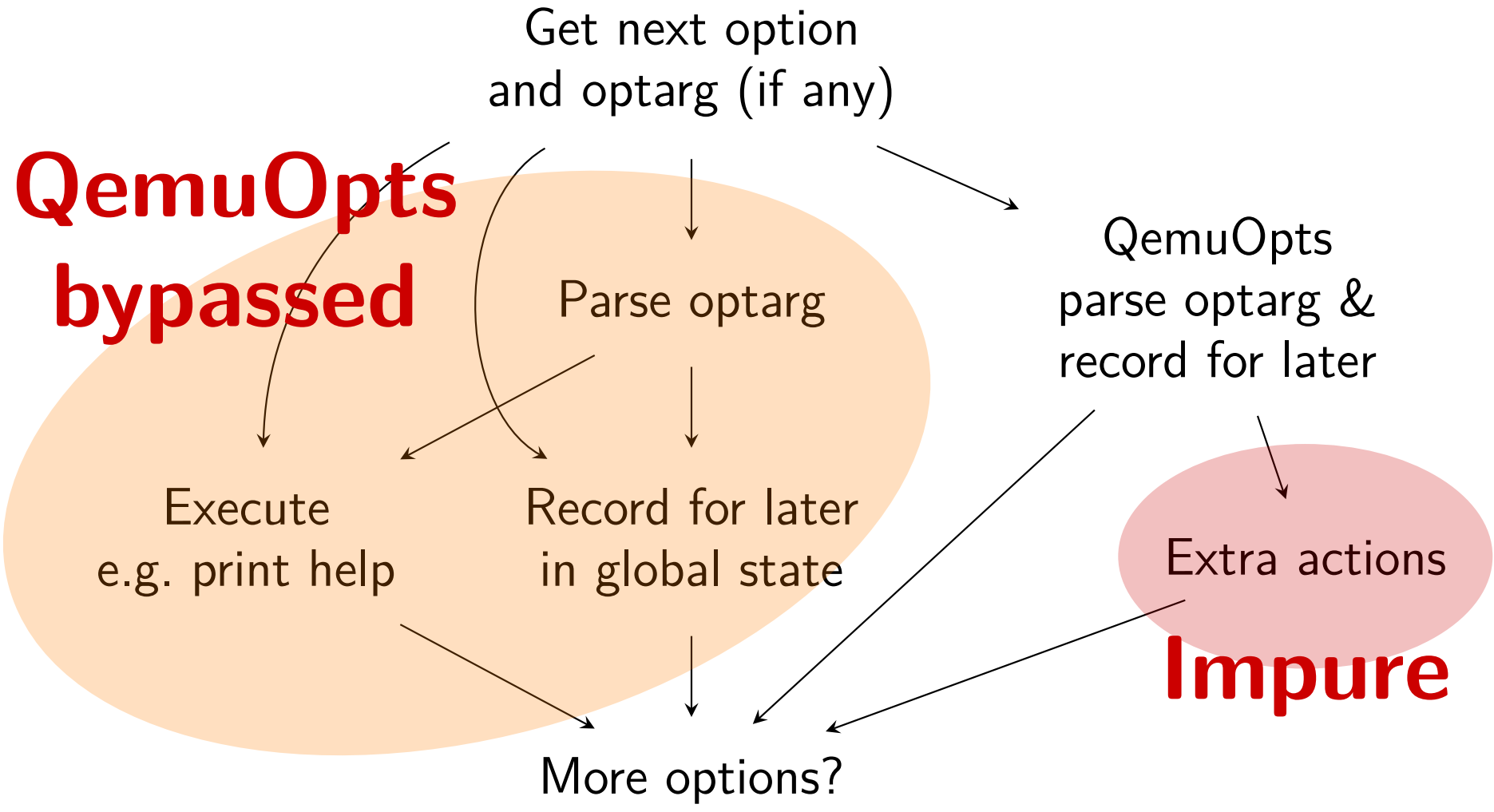

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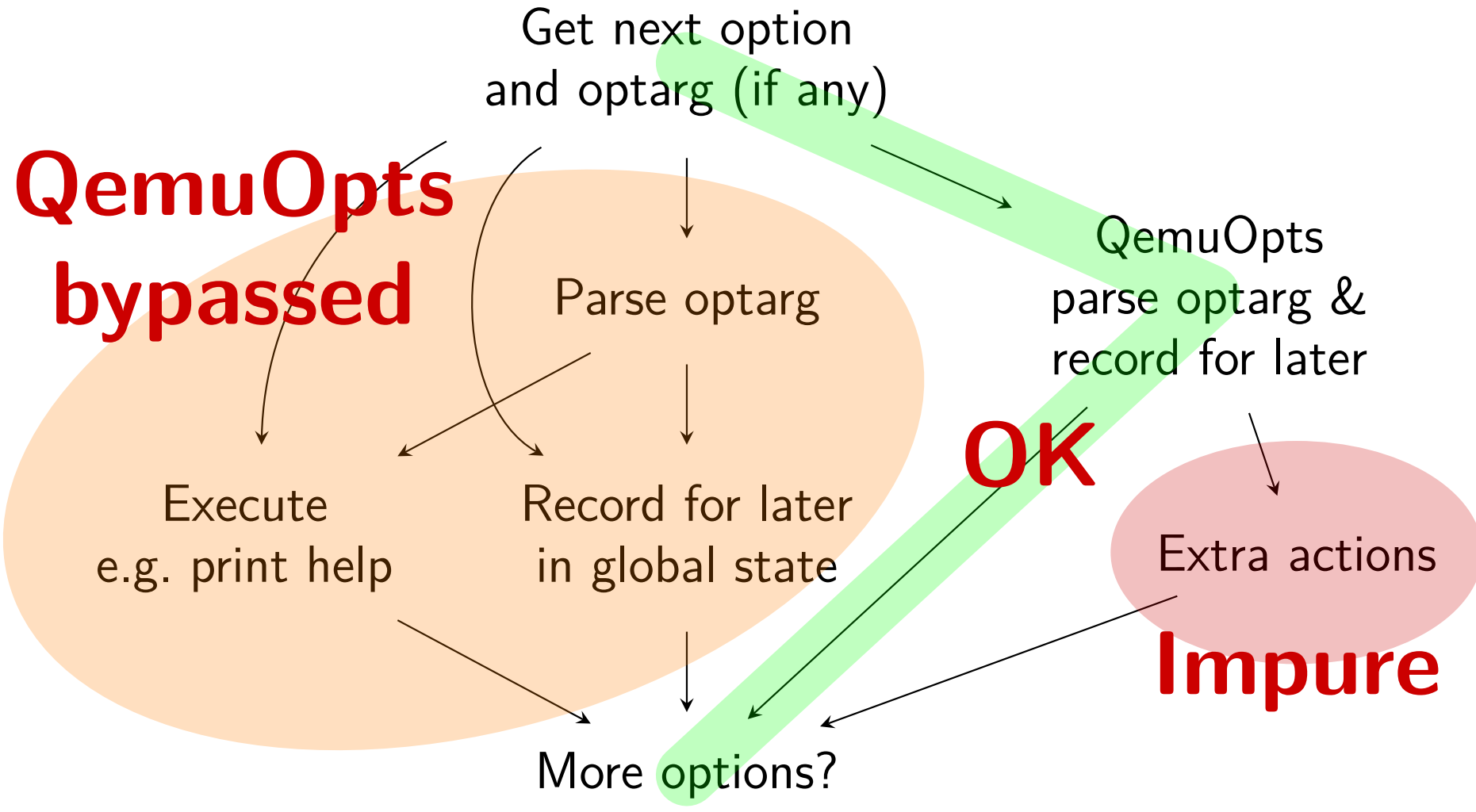


Impact on CLI config files

Config files apply to QemuOpts state:

- `-writeconfig` writes it out
- `-readconfig` reads it in

Impact of QemuOpts' sad state on config files:

- Okay: works
- Impure: broken (extra actions skipped)
- Bypassed: not supported

Config files work for one out of five options

Impact on introspection

Introspection is based on QemuOpts:

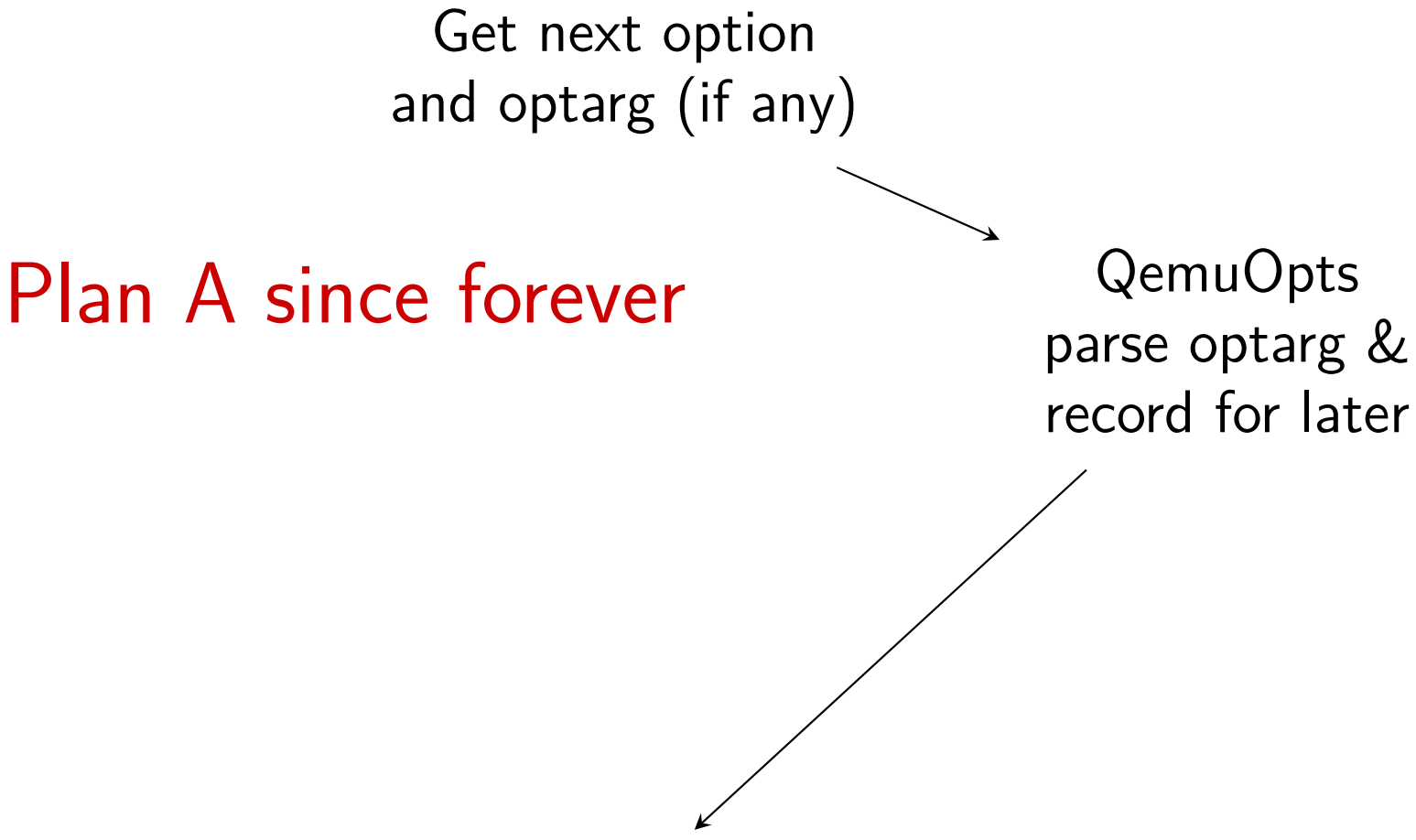
> QMP's `query-command-line-options` has no other source of truth

Impact on introspection:

- Okay: works
- Impure: works anyway
- Bypassed: not supported

Can introspect one out of five options

Fix by QemuOpts taking over?



Plan A since forever

Fix by QemuOpts taking over?

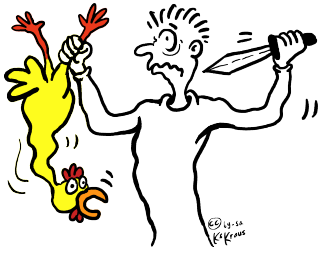
Get next option
and optarg (if any)

QemuOpts
parse optarg &
record for later

More options?

Plan A since forever

Problem: stay compatible to
20+ ad hoc parsers



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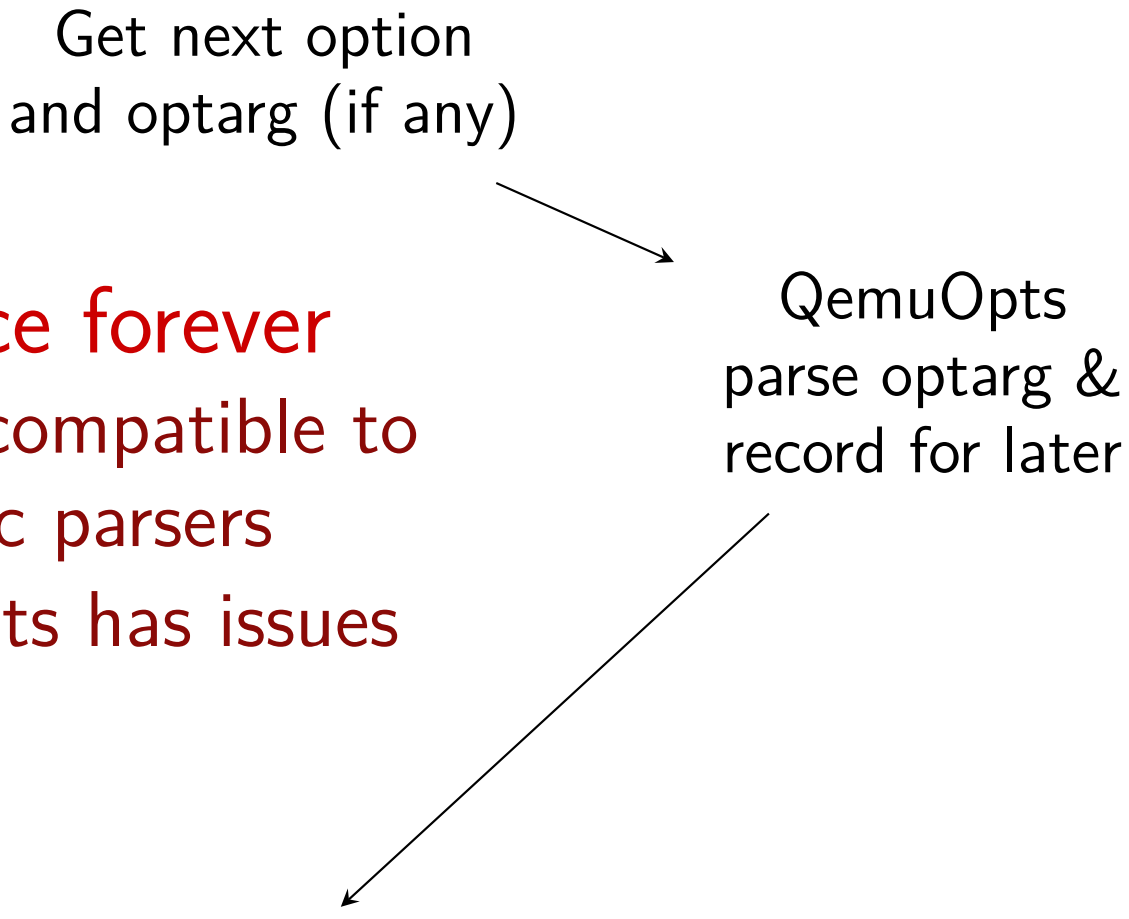

Plan A since forever

Problem: stay compatible to 20+ ad hoc parsers

Also: QemuOpts has issues

QemuOpts' data model

Derived from abstract *key*=*value*,... syntax:

- Keyword parameters, all optional
- Parameter values are strings

Encapsulated in type `QemuOpts`:

- Parameters are dynamically typed

Thrown in for convenience:

- Can restrict values to integer or bool

Stupidest model that could possibly work

Simple example: -msg

-msg has just one bool parameter timestamp

QemuOpts declaration:

```
static QemuOptsList qemu_msg_opts = {
    .name = "msg",
    [boilerplate omitted...]
    .desc = {
        {
            .name = "timestamp",
            .type = QEMU_OPT_BOOL,
        },
        { 0 }
    },
};
```

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Parameter name and type

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Note: option *argument* definition is separate from *option* definition

Next example: -numa

`-numa` has a mandatory parameter `type`
Additional parameters depend on value of `type`
(e.g. with `type=node`, we have parameter `nodeid`)

QemuOpts declaration:

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```

Best QemuOpts can do:
accept any key, with string value
(bye, bye introspection)

Code to parse -numa's optarg

```
QemuOptsList *list = qemu_find_opts("numa");
QemuOpts *opts = qemu_opts_parse(list, optarg,
                                 [details...]);
[error out if !opts...]
const char *type = qemu_opt_get(opts, "type");
if (!type) {
    [error out...]
} else if (!strcmp(type, "node")) {
    const char *s = qemu_opt_get(opts, "nodeid");
    uint64_t nodeid = qemu_strtou64(s, [...]);
    [more checking...]
} else [more cases...]
```

Code to parse -numa's optarg

Find the declaration

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QemuOptsList *list = qemu_find_opts("numa");
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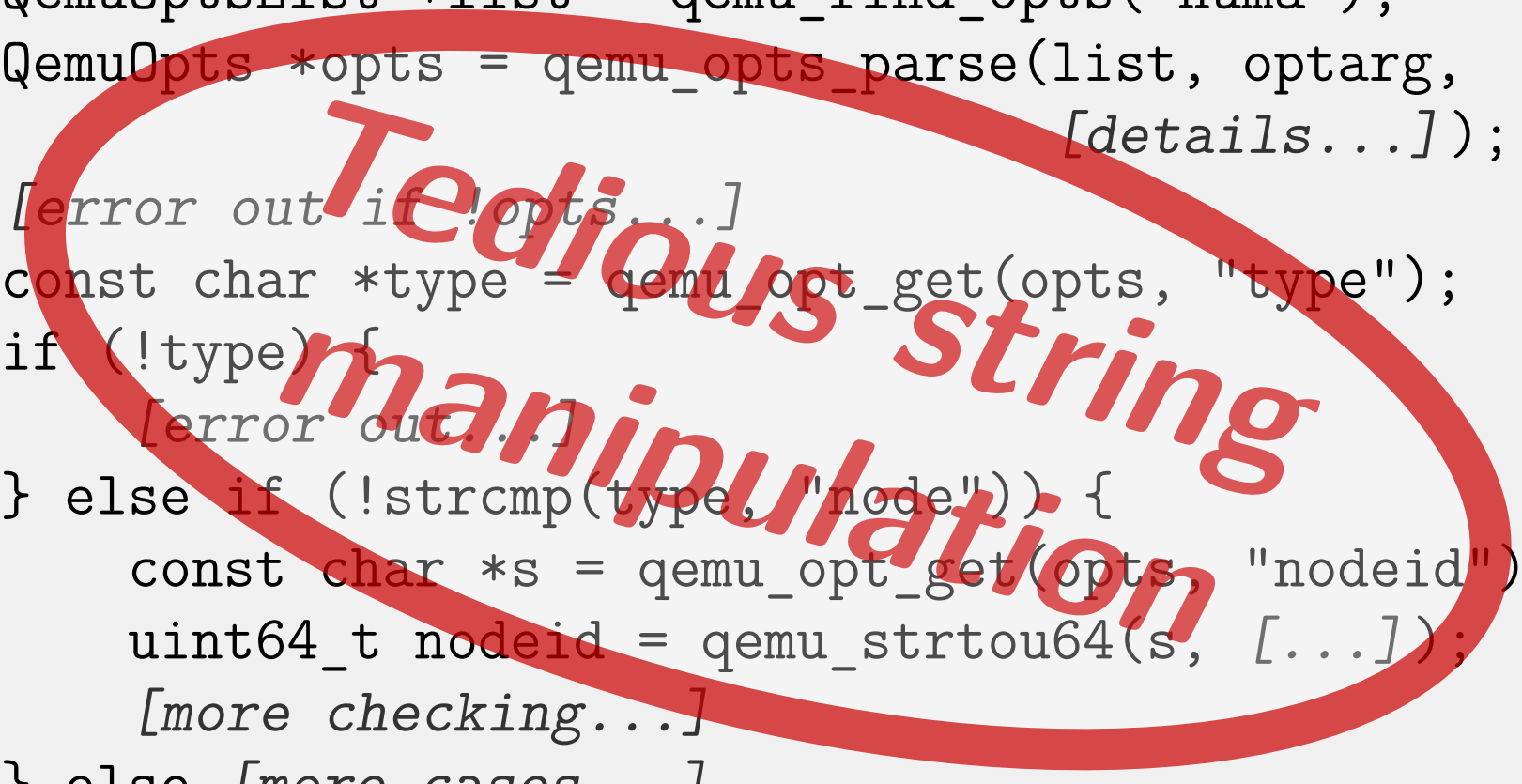
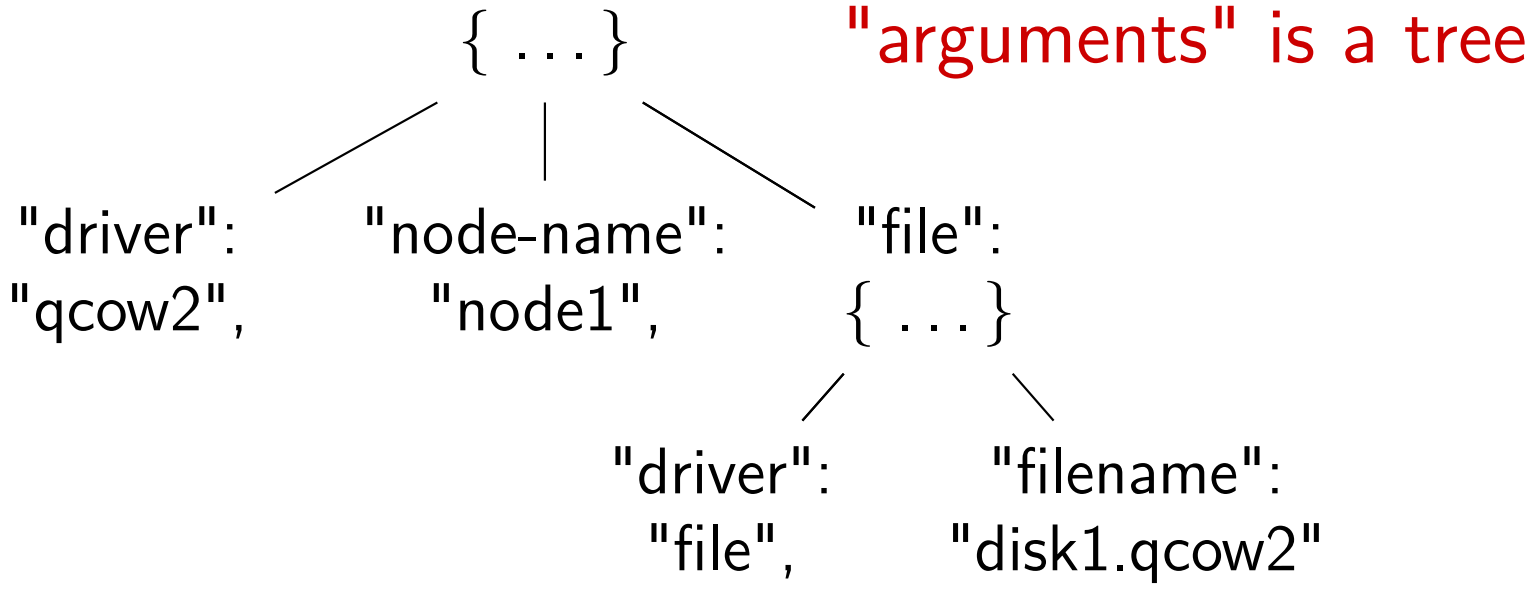


Third example: -blockdev

`-blockdev` is like QMP `blockdev-add`

```
QMP> {"execute": "blockdev-add", "arguments": {
        "driver": "qcow2", "node-name": "node1",
        "file":{ "driver": "file",
                 "filename": "disk1.qcow2"}}}
```



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But QemuOpts is by design flat...

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```

But QemuOpts is by design flat...

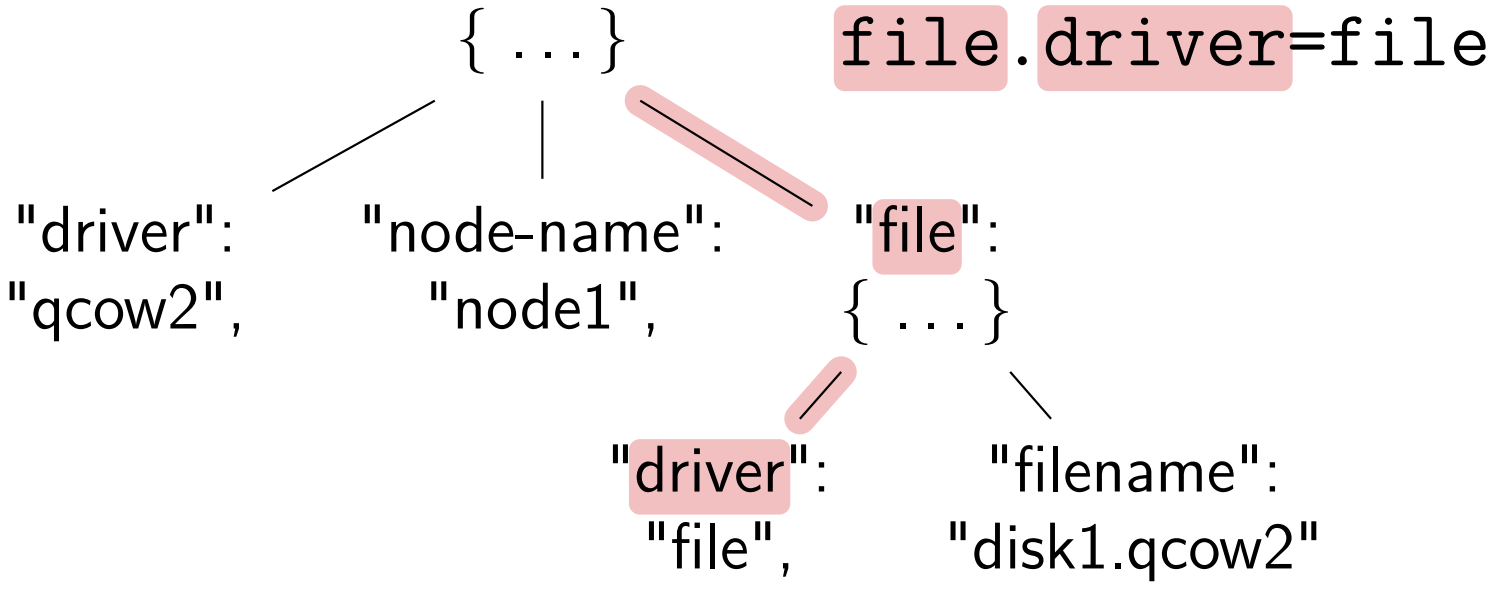
Flatten the arguments tree with dotted keys:

```
-blockdev driver=qcow2,node-name=node1,\
file.driver=file,file.filename=tmp.qcow2
```

Dotted keys in a nutshell

Basic idea:

- Specify tree by listing its (string-valued) leaves
- Dotted key encodes path to leaf



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Clever, but has issues:

- Bolted onto QemuOpts

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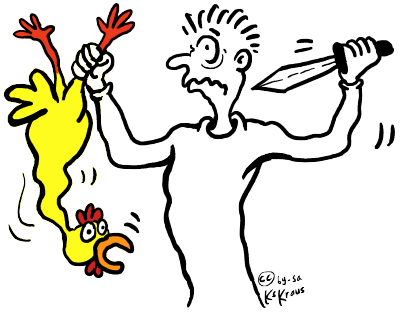

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- Inconsistent with *other* workarounds
  (to be kept for backward compatibility)
- Can express most, but not all trees
- More, but we're running out of time

Needs our CLI fails to meet

Config files: incomplete & inadequate

Expressive power: weaker than QMP

Single C interface: tedious glue code needed

Introspection: anemic compared to QMP

Part III
Solutions

Actual code to parse -numa

```
Visitor *v;
NumaOptions *numa;

v = opts_visitor_new(opts);
visit_type_NumaOptions(v, NULL, &numa, &err);
visit_free(v);
if (!numa) {
    [error out...]
}
switch (numa->type) {
case NUMA_OPTIONS_TYPE_NODE:
    uint16_t nodeid = numa->u.node.nodeid;
    [more...]
[more cases...]
```

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QAPI type for -numa's optarg

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```

Check and map to QAPI type

Actual code to parse -numa

```
Visitor *v;
NumaOptions *numa;

v = opts_visitor_new(opts);
visit_type_NumaOptions(v, NULL, &numa, &err);
visit_free(v);
if (!numa) {
    [error out...]
}
switch (numa->type) {
case NUMA_OPTIONS_TYPE_NODE:
    uint16_t nodeid = numa->u.node.nodeid;
    [more...]
[more cases...]
```

Look Ma, no strings!

Okay, but what's a QAPI type?

QAPI types are defined in a QAPI schema like this:

```
{ 'union': 'NumaOptions',
  'base': { 'type': 'NumaOptionsType' },
  'discriminator': 'type',
  'data': {
    'node': 'NumaNodeOptions',
    [more variants...] }}
{ 'enum': 'NumaOptionsType',
  'data': [ 'node', [more values...] ] }
```

QAPI compiles them to C types plus code for serializing to/from JSON, introspection, ...

QAPI C type NumaOptions

```
typedef enum NumaOptionsType {
    NUMA_OPTIONS_TYPE_NODE = 0,
    [more type values...]
} NumaOptionsType;

struct NumaOptions {
    NumaOptionsType type;
    union { /* union tag is @type */
        NumaNodeOptions node;
        [more variants...]
    } u;
};
```

Where QAPI beats QemuOpts

- More expressive type system
  - enumerations
  - algebraic types
  - arbitrarily nested
- More precise introspection
- Generated C types beat `QemuOpts` & strings
  - Interfaces made for QMP use nice C types
  - Interfaces made for CLI use `QemuOpts` (and suck)
  - Driving single interface requires conversion

Fix by mapping to QAPI types?

Mapping QemuOpts to QAPI looks like progress

$\rightsquigarrow$ Plan B: QemuOpts mapped to QAPI takes over

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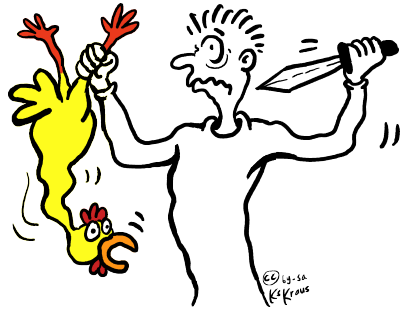

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Fixable, but too much stuff bolted onto QemuOpts

$\rightsquigarrow$ Plan C: QAPI takes over
Status: cooking ☺

QAPIfy CLI option definition

```
##
# @--msg:
# prepend a timestamp to each log message
##
{ 'option': '-msg',
  'data': { '*timestamp': 'bool' },
  'help': [
    "-msg timestamp[=on|off]",
    "      change the format of messages",
    "      on|off controls leading timestamps"] }
```

Observe:

- Option defined in *one* place: QAPI schema
- Like QMP command less 'returns' plus 'help'

QAPI-generated code

All option definitions together compile to:

```
QAPIOption *qapi_options_parse(int argc,
                               char *argv[]);
```

Takes argument vector

Returns array of parsed options `QAPIOption[]`
`QAPIOption` is tagged union of option arguments

New code to parse -numa

```
Visitor *v;
NumaOptions *numa = qopt[i].u.numa;

v = opts_visitor_new(opts);
visit_type_NumaOptions(v, NULL, &numa, &err);
if (!numa) {
    [error out...]
}
switch (numa->type) {
case NUMA_OPTIONS_TYPE_NODE:
    uint16_t nodeid = numa->u.node.nodeid;
    [more...]
[more cases...]
```

QemuOpts middleman cut out

Alternative optarg syntax: JSON

`qapi_options_parse()` supports JSON in addition to dotted *key*=*value*,...

Dotted keys are

- nicer for simple cases
- needed for backward compatibility 

JSON is

- more general
- recommended for programmatic use

Can this meet our CLI needs?

Config files ✓ (JSON)

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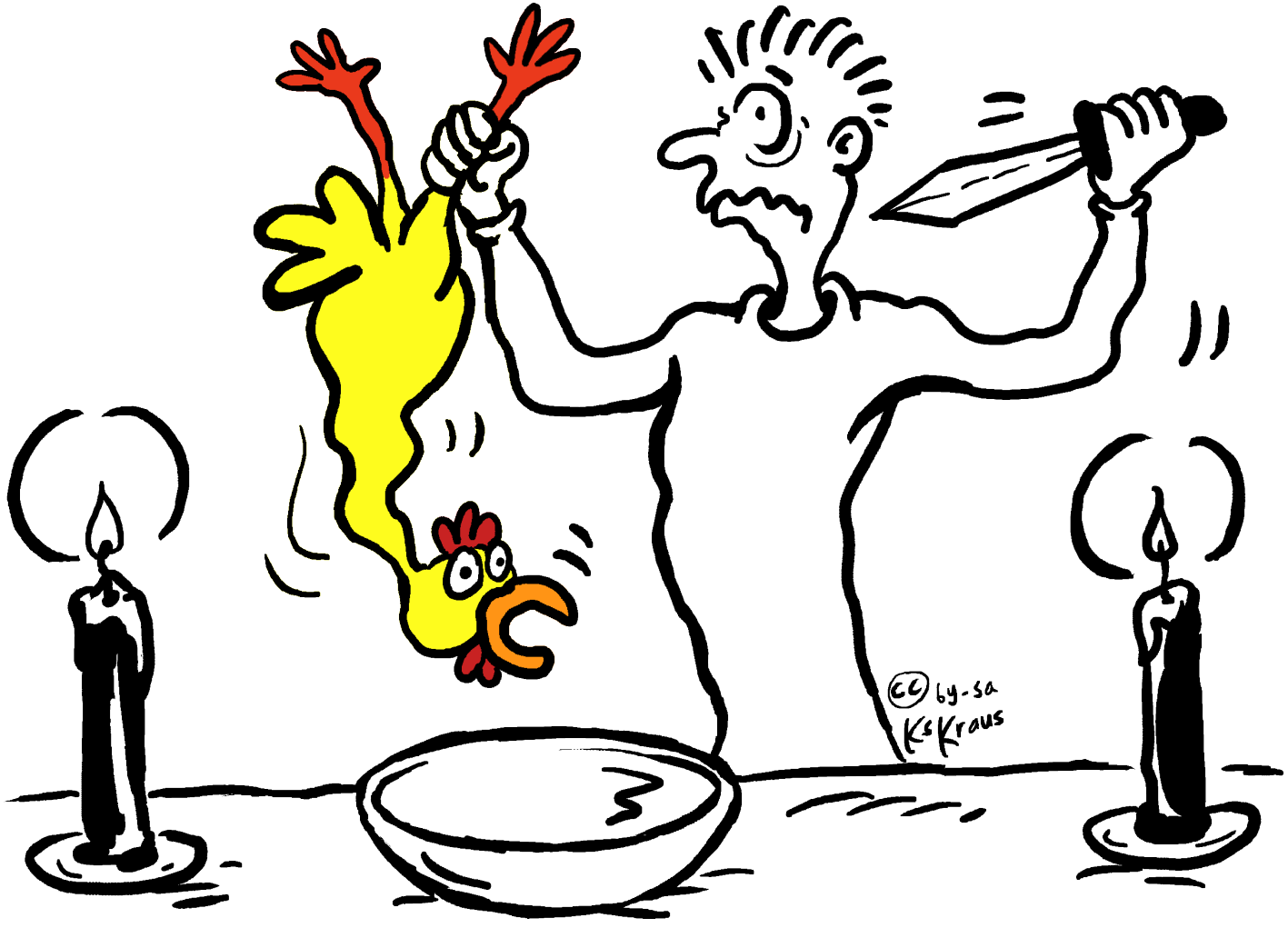
Backward compatibility ?

Backward compatibility



Backward compatibility

- Existing 20+ ad hoc parsers
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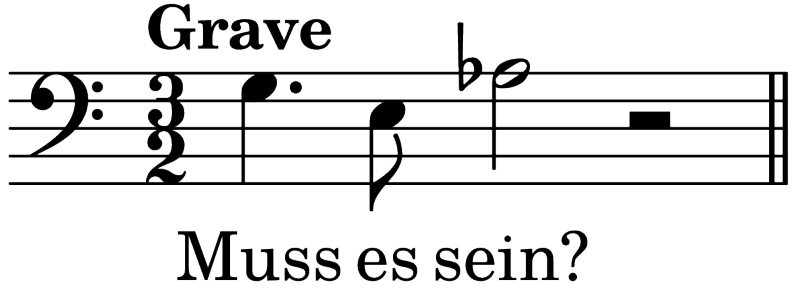
- Existing bolted-on conversion to QAPI
  - Replicate its extra features and corner cases: flattening, integer lists, ...
- QemuOpts eccentricities
  - Replicate those too: syntactic sugar, trickery around repeated keys, special key `id`, ...

Must it be?



Backward compatibility is a choice

We choose how much pain to inflict on ourselves to avoid inconveniencing users

Up to what point are the opportunity costs worth it?

Status: cooking, needs work

Posted: [RFC PATCH] Command line QAPIfication

Highlights and (some of the) lowlights:

- All options QAPIfied
- Most option arguments not fully QAPIfied, yet
  (backward compatibility work hiding here)
- Introspection works
- Config file not yet implemented
- Generated docs look more terrible than usual

Questions?

Thanks & good bye

You might find these links useful:

- [RFC PATCH] Command line QAPIfication
  http://lists.gnu.org/archive/html/qemu-devel/2017-10/msg00209.html
- QEMU interface introspection: from hacks to solutions
  http://www.linux-kvm.org/page/KVM_Forum_2015

No rubber chickens were harmed in the making
of this presentation